U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-294 193

Resource and Environmental Profile Analysis of Five Milk Container Systems

Midwest Research Inst, Kansas City, MO

Prepared for

Environmental Protection Agency, Washington, DC Office of Solid Waste

1978

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No. PB294193

4. Title and Subtitle

Resource and Environmental Profile Analysis of Five Milk Container Systems

5. Report Date

1978

6.

7. Author(s)

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8. Performing Organization Rept. No.

9. Performing Organization Name and Address

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10. Project/Task/Work Unit No.

11. Contract/Grant No.

68-01-2953

12. Sponsoring Organization Name and Address

United States Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
Washington, D.C. 20460

13. Type of Report & Period Covered

Final Report

14.

15. Supplementary Notes

16. Abstracts

This study provides a comparison of the resource and environmental implications of using a variety of refillable and nonrefillable containers for the delivery of fluid milk. The study uses a resource and environmental profile analysis to compare the resource inputs and environmental outputs of each of the systems evaluated. Resource inputs are raw materials, energy and water. Environmental outputs are industrial solid waste, atmospheric emissions, waterborne wastes, and postconsumer solid waste. The study compares milk delivered in paperboard cartons, nonrefillable plastic bottles, refillable plastic bottles, refillable glass bottles, and plastic pouches.

17. Key Words and Document Analysis. 17a. Descriptors

Milk Containers, Plastic Milk Bottles, Plastic Milk Pouch, Refillable Milk Bottle, Paperboard Milk Container, Milk Packaging.

17b. Identifiers/Open-Ended Terms

Resource and Environmental Profile Analysis (REPA)

17c. COSATI Field/Group

1.

18. Availability Statement

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
225

22. Price
A10 - A01

FORM NTIS-35 (REV. 3-72)

USCOMM-DC 14952-P72

PB 294193

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS OF FIVE MILK CONTAINER SYSTEMS

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U.S. ENVIRONMENTAL PROTECTION AGENCY

1979

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U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

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An environmental protection publication (SW-168c) in the solid waste management series.

Foreword

At one time milk was delivered virtually exclusively in refillable bottles. The relatively recent shift to nonrefillable containers has been a source of concern to environmentalists. Most suspected that any change from refillable to single-use containers was inherently bad from an environmental perspective. This office sought to examine that shift in order to replace suspicion with reason. The principal purpose of this study, then, was to provide a comparison of the resource and environmental implications of using a variety of refillable and nonrefillable containers for the delivery of fluid milk.

The study does not deal with a number of other questions that a responsible planner or policy maker would ask regarding milk containers. This is intentional. For example, the study only touches on questions that have been raised concerning health and nutrition. These issues are discussed in the report because representatives of the milk container industry indicated to us that they were matters of serious concern and debate within their industry. However, we have drawn no conclusions on the question of how different container types affect health and nutrition. Only the Food and Drug Administration and State health authorities have the power or ability to render final judgements in these areas. The Environmental Protection Agency has no interest in inserting itself into those debates and discussions.

Earlier drafts of the study also attempted to describe economic differences among the various containers. That investigation was dropped, though, because the comparative costs of milk container systems vary too widely among communities, regions, and individual businesses to generalize about them in this report.

In this study, we have used a Resource and Environmental Profile Analysis (REPA) to compare milk container alternatives. The well informed reader should recognize that any study using a methodology as complex as that for a REPA must involve a number of assumptions and judgements. The reader should consider carefully the assumptions and reservations noted in Chapter 2. We believe that the assumptions made are appropriate but we recognize that the milk industry is not unanimous in its acceptance of them. Nevertheless, it is necessary to be familiar with these assumptions in order to understand the report fully and to judge its implications correctly.

This report should be useful to those, both in government and in industry, who seek to establish or change environmental and resource use policies. We believe that it will serve in that effort, taken in its proper perspective as one of the pieces of the decision-making framework.

Steffen W. Plehn
Deputy Assistant Administrator
for Solid Waste

PREFACE

The objective of this research study is to describe the environmental and health aspects of the following five milk container systems: (1) refillable glass; (2) refillable plastic; (3) nonrefillable plastic; (4) nonrefillable paperboard; and (5) nonrefillable plastic pouch. Economic aspects were considered in the draft report but have been excluded from the final report due to the lack of sufficient data to present an objective comparison of the five systems.

The research effort was conducted for the United States Environmental Protection Agency (Resource Recovery Division - Office of Solid Waste Management). The study was conducted under the general supervision of Mr. Robert Levesque, Manager of Technoeconomics Programs at Midwest Research Institute. The project leader and a principal investigator was Mr. Richard O. Welch, Senior Industrial Research Analyst. Health aspects were considered by Mr. Ron Fellman, aided by Ms. Mary Simister. Mr. Denis Viscek provided the analysis of the economic aspects with counsel from Mr. Charles Romine.

The co-principal investigator for the resource and environmental aspects was Mr. Robert G. Hunt, Franklin Associates, Ltd., a subcontractor to MRI. Mr. Hunt developed the data for the glass and paperboard systems. Mr. William E. Franklin of Franklin Associates, Ltd., provided managerial review functions for the subcontractor.

The research team is greatly indebted to many companies and organizations for the active support they provided during the course of the study. A list of data contributors is presented in the Bibliography section.

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CHAPTER 1

INTRODUCTION

This study is a resource and environmental profile analysis (REPA) of five milk container systems accompanied by chapters concerned with health and nutritional aspects of the five containers.

This final report was preceeded on June 18, 1976 by a draft report which addressed economic considerations in addition to REPA, health and nutritional aspects. The economics report has been excluded from the final report due to lack of readily available information which would permit an objective comparison of the various systems. Such an analysis should evaluate: employment shifts, raw materials availability, new capital investments, cost to redirect existing capital investments, labor productivity, costs to the consumer, regional effects, etc.

The purpose of this report is to provide government and industry representatives with selected environment overviews of the five milk container systems. This report, by itself, should not be the sole basis of making policy or legislative recommendations. Many other factors, i.e., economic impacts, availability of resources, toxicity of environmental pollutants, regional impacts, social implication, etc., are also important and should be part of a comparative product analysis.

The majority of the resource and environmental information presented in the report is based on a representative weight for each of the containers. MRI acknowledges weights for the same type of container vary across the country, and that since 1974 (the starting year for the research study) the trend in most milk containers has been toward lighter weight packaging. For example, the three quart nonrefillable paperboard container, now being used in parts of the country, has a more favorable milk to packaging weight ratio than the gallon paperboard container. Also, the inplant molded nonrefillable plastic container is substantially lighter than the custom molded container used in this report. Therefore, the research data applies to the specific containers included in the study. MRI does not purport that the results are applicable to every milk container on the market without obvious adjustments in the profile impacts due to differences in material requirements, fabrication impacts, etc.

As mentioned above, this final report was preceeded by a draft report which was distributed for industry review. Those organizations wishing to comment on the study were asked to submit their recommendations to the Environmental Protection Agency. The Agency reviewed the comments and selected several of the recommendations for incorporation into the final report. Revisions to the draft report are primarily concerned with: (1)

expanding the discussions on REPA methodology to accentuate the critical assumptions and limitations; (2) eliminating the economics section; (3) reworking and greatly condensing the sections on health and nutrition; (4) revising the compactability data for paperboard and plastic containers; and (5) placing the REPA, health, and nutrition sections in a single volume.

Chapter 2 contains a brief summary of the resource and environmental profile analysis (REPA) methodology. The summary of the REPA information is contained in Chapter 3. Discussions of the profiles of the individual container systems are presented in Chapter 4.

Chapters 5 and 6 represents MRI's investigations of "Public Health and Sanitation Concerns" and "The Effects of Light on Flavor and Nutrition," as they relate to the five milk container systems. These investigations were undertaken as a supplement to the original REPA study, in response to industry concerns that environmental impacts could not be fairly presented without an accompanying discussion of health impacts. In accordance with our prescribed scope of work, MRI has performed a comprehensive investigation of the regulatory structure governing milk containers and has compiled extensive data reflecting issues of concern to academicians, industry representatives and public health officials. However, we have made no attempt to pass judgments or perform any original research relating to these issues. The information presented is not intended to be a basis for policy decisions, but rather to present an overview of health regulations and to highlight areas of concern within that framework.

In summary, MRI's study revealed three concerns relating specifically to the returnable polyethylene container, only one of which has real public health implications; i.e., the absorption of potentially hazardous chemical compounds. Chapter 5 presents data which detail this concern but concludes that the container system is currently operating within the federal regulatory mandate, as specified by the Food and Drug Administration (FDA). In Chapter 6, MRI concluded that no definitive data are available to indicate that light-induced off-flavor development in milk is a public health concern, and that no documented evidence exists to indicate significant nutritional losses associated with a particular container type.

Considerably more data were gathered in this study than could be presented in this document. The reader is encouraged to consult the bibliography for sources of additional information.

CHAPTER 2

SUMMARY OF REPA METHODOLOGY

The resource and environmental profile analysis (REPA) technique is a systems approach used to quantitate the resource inputs and environmental outputs of various product systems. Resource inputs are defined as raw materials, energy and water, while environmental outputs are represented by industrial solid waste, atmospheric emissions, waterborne wastes, and postconsumer solid waste. A product system is represented by all of the processes from raw materials extraction through raw materials processing, the manufacture of intermediate products, production of the final product, reuse or recycle of the product and disposal of the product (see Figure 8).

The manufacture, use, and disposal of products will result in some form of environmental degradation, i.e., depletion of natural resources, air pollution, water pollution, aesthetic blight, creation of health hazards, alteration of food chains, etc. It would be ideal if an objective analysis could present a quantitative assessment of each type of environmental degradation associated with a product system. However, this is not the case. The precise extent to which each resource and environmental impact affects the biosphere cannot be readily determined (although there may be general agreement that degradation has occurred). The point of view taken in the REPA technique is that even though the complete effects of environmental degradation cannot be determined, it is useful to establish reliable estimates of the relative impacts of competitive products. Thus, even if the total effects of material and energy use or environmental pollutants are not known, it is very useful to establish the relative levels of the impacts. In many cases it may be concluded that a product responsible for more resource use, and the release of more pollutants (than a competitive product), will produce more environmental degradation.

The critical assumptions and limitation of the REPA technique used in this study are discussed below (for more detail, see Chapter 4).

A. Wood Waste Energy

In this study the energy profiles for the paperboard system are presented in two ways: (1) energy derived from wood wastes is not counted in the total energy summation; and (2) wood waste energy is included in the total energy summation.

If wood is viewed strictly as a material resource then the use of wood wastes to produce energy would not be viewed as depletion of fuel resources (then wood derived energy would not be counted in the total system energy). However if wood is being considered as an energy resource, then the use of wood wastes would constitute a depletion of fuel reserves (then wood derived energy would be included in the total system energy). On a worldwide basis, slightly less than half of the wood harvested is used as a fuel, with the remainder being used as a material resource. Thus, wood serves for either use.

The use of wood "wastes" to produce energy implies that the wastes probably have limited value, or small potential of being used as a raw material at this time. The black liquor from the draft pulping process is the primary source of energy from wood wastes. There is essentially no market for this liquor outside the paper mill. The use of these wood wastes do not deplete a natural material or energy resource at this time. However, should wood become a primary source of fuel in this country, then timber growth would not keep up with wood demand and a depletion of a material and energy resource would occur. This report does not purport that wood wastes should or should not be counted in the total energy profiles, but to present the energy profiles as they exist under both viewpoints.

B. Hydrocarbon Feedstocks

Petroleum and natural gas raw materials are counted as their energy equivalent rather than as pounds of raw materials. These materials are not considered to be renewable resources. Therefore, since the use of oil and gas constitutes a depletion of natural energy resources, our viewpoint is that treating these materials as energy inputs rather than as a physical quantity of material, is a more accurate statement of environmental impact.

C. Renewable Versus Nonrenewable Resources

Oil and gas are generally considered to be nonrenewable resources while wood is considered to be renewable. The renewable and nonrenewable issue becomes important when considering if or how the use of materials should be weighted. In the REPA technique, no attempt is made to weight material use based on scarcity or amount of readily recoverable materials. Since the use of wood fiber constitutes the use of a conditionally renewable resource, one viewpoint is that its use should be considered a favorable aspect of a products profile in contrast to the use of oil or gas which depletes a nonrenewable resource. It is recognized that wood is renewable, that oxygen is a by-product of forest growth, etc., however, the growth of wood does cause the removal of some soil constituents which will eventually need to be replaced. In this report, MRI does not attempt to assign a weighting factor for specific materials based on renewable or nonrenewable aspects, except to count hydrocarbon raw materials as energy.

D. Biodegradable Versus Nonbiodegradable

The decomposition rate of postconsumer solid waste items is not a consideration in the REPA methodology. Weighting factors, based on rate of decomposition of exposed and buried solid wastes are not used.

The degradation characteristics were not considered due to the difficulty involved in quantitatively accessing the environmental impacts. Degradable material would be helpful in controlling exposed litter. However, the quality of being a degradable product in a landfill has both positive and negative aspects. A positive benefit is that the waste goes away. Negative aspects are that degradation can result in air and water pollution and landfill instability.

Paper products will generally degrade faster than plastics. A common misconception is that plastic remains intact indefinitely. Research concerning buried wastes have shown that plastics degrade by the action of: oxygen, hydrolysis, microorganisms, stress cracking, insects, marine creatures, etc. (Ref. 90). Plastics which degrade quickly can be produced should the market demand degradable materials.

E. Postconsumer Solid Waste Compactability

In the draft report (submitted June 18, 1976) the glass bottle was assumed to retain 65 percent of its volume when landfilled, while the plastic and paper containers (excluding the plastic pouch) were assumed to retain 10 percent of their volume. These estimates were used in the absence of comparable research data which would present an object comparison for the containers. At the time of this final report, only one document[89] has been made available to the research team regarding the compactability of paper and plastic milk cartons, and no information has been received on the landfill volume of the glass container. The report by Baribo and Moruss indicates that the nonrefillable plastic bottles retain approximately 60 percent of their original volume while paper cartons retain 22 percent, under the test pressures used. Perhaps more significant than the actual crushed volumes recorded in the test, is the ratio of pressures required to keep the containers in a crushed condition. The plastic bottle required 18.8 kilograms and the paper carton 5.5 kilograms, a ratio of 3.4 to 1 (plastic to paper). The ratio of crushed volumes was 2.43 to 1 (plastic to paper). This report will reflect the results of the Baribo and Moruss study and assume that plastic cartons will retain 65 percent and paper cartons will retain 22 percent of their original volumes. This relationship is assumed for each size of container. The refillable plastic container will also be assigned the 60 percent retention value.

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CHAPTER 3

SUMMARY OF RESEARCH RESULTS FOR THE RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS (REPA)

In this phase of the study, the resource inputs and environmental outputs are determined for the five milk container systems. Each system is composed of several subsystems such as raw materials extraction, materials processing, container manufacture, etc. For each subsystem, seven impact categories (raw materials, energy, wastewater volume, solid wastes, atmospheric emissions, waterborne wastes, and postconsumer solid wastes) are quantified. The purpose of this summary section is to bring together the impacts for each subsystem, and form one set of impact data representing the summary values for the seven impact categories. The summary values are presented for 1,000 gallons of milk delivered in each container system.

A. Milk Container Description

A description of each container system analyzed is presented in Table 1. The plastic milk bottles are made from high density polyethylene (HDPE), while the plastic pouch material is low density polyethylene (LDPE). The paperboard container is manufactured from bleached kraft paperboard coated with LDPE.

The closures and closure weights were selected from representative closures in common use. In the dairy industry, closures are available in paper, plastic, steel, and aluminum and weigh from 0.65 gram to 6 grams each. For this study, a 2.3 gram paper closure was used for the refillable glass and plastic gallon and half gallon bottles, while a 0.65 gram paper closure was assumed for the half pint sizes. A 2.3 gram plastic closure was selected for the nonrefillable plastic gallon and half gallon, while the 0.65 gram paper closure was used for the half pint. The paperboard and plastic pouch containers do not utilize a separate closure. The closure selections used in this study do not represent any endorsement or preference by MRI regarding the type or material composition of the closure. The paper and plastic closures were selected because our REPA data bank contains more updated information on these two materials than on the steel or aluminum systems.

B. REPA Summary Data

The summaries of the resource and environmental impacts for the delivery of 1,000 gallons of milk in one gallon, half-gallon and half-pint milk containers are presented in Tables 2, 3, and 4.

(18)

TABLE 1

BASIC DESCRIPTION OF MILK CONTAINERS ANALYZED
(in grams per component)

Container/component description	Container size		
	Gallon	Half-gallon	Half-pint
Refillable glass bottle (RET-GLS)			
Container	1,452	921	227
Handle	10.0	--	--
Closure	2.3	2.3	0.65
Refillable plastic bottle (RET-PLS)			
Container	160	126	34
Handle	5.7	5.7	--
Closure	2.3	2.3	0.65
Nonrefillable plastic bottle (NR-PLS)			
Container	70[a]	40	12
Closure	2.3	2.3	0.65
Nonrefillable paperboard carton (PB)			
Container[b]	115	62	11.5
Handle	1.6	--	--
Nonrefillable plastic pouch (PCH)			
Container	15.3	7.6	2.0
Bag	12.5	--	--
Pitcher	173	173	--
Straw	--	--	0.30

Source: Midwest Research Institute.

[a] This weight represents the market average when the study data was collected in 1974. The current in-plant blow-molded bottles (which represent the majority of the market and the current trend in plastic carton production) weigh between 55 and 60 grams.

[b] The current trend in paperboard cartons is showing lighter container weights per volume of milk.

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TABLE 2

SUMMARY IMPACT DATA FOR 1,000 GALLONS OF MILK DELIVERED
(In one gallon containers by type of container system)

		Milk Container Systems										
		Refillable Containers							Nonrefillable Containers			
		Glass Bottle			Plastic Bottle				Plastic Bottle	Paperboard Carton[a]	Paperboard Carton[b]	Plastic Pouch
Impact category	Units	5-Trip	10-Trip	20-Trip	5-Trip	10-Trip	20-Trip	50-Trip	1-Trip	1-Trip	1-Trip	1-Trip
Raw materials[c]	lb	954.15	480.03	242.97	21.88	14.83	11.31	9.20	17.70	238.88	238.88	2.34
Energy	10^6 Btu	7.42	4.41	2.90	4.98	3.08	2.13	1.56	8.78	6.20	8.62	3.59
Water	10^3 gal.	1.29	0.86	0.64	0.69	0.55	0.48	0.44	0.66	2.87	2.87	0.32
Industrial solid waste	cu ft	2.12	1.10	0.60	0.27	0.18	0.14	0.11	0.38	0.85	0.85	0.13
Atmospheric emissions	lb	32.67	20.93	15.07	19.80	13.70	10.67	8.81	30.86	26.08	26.08	14.02
Waterborne waste	lb	6.26	4.76	4.01	4.08	3.61	3.38	3.32	3.13	6.24	6.24	1.51
Postconsumer solid waste	cu ft	19.92	10.02	5.02	16.24	8.46	5.06	2.00	75.43	30.39	30.39	1.05

Source: Midwest Research Institute.

a/ Total energy without including energy derived from burning wood wastes.

b/ Total energy after including 2.42×10^6 Btu of energy derived from burning wood wastes.

c/ Hydrocarbon feedstocks are counted as energy rather than pounds of raw materials. Wood fiber, sand, etc., are counted as pounds of raw materials.

TABLE 3

SUMMARY IMPACT DATA FOR 1,000 GALLONS OF MILK DELIVERED
(In half gallon containers by type of container system)

		Milk Container Systems										
		Refillable Containers							Nonrefillable Containers			
		Glass Bottle			Plastic Bottle				Plastic Bottle	Paperboard Carton[a]	Paperboard Carton[b]	Plastic Pouch
Impact category	Units	5-Trip	10-Trip	20-Trip	5-Trip	10-Trip	20-Trip	50-Trip	1-Trip	1-Trip	1-Trip	1-Trip
Raw materials[c]	lb	1,213.46	611.92	311.15	34.80	23.91	17.87	14.49	20.45	249.11	249.11	1.00
Energy	10^6 Btu	9.43	5.61	3.70	7.75	4.68	3.13	2.21	10.13	6.46	9.04	2.37
Water	10^3 gal.	1.59	1.04	0.76	1.26	1.01	0.89	0.82	0.72	3.07	3.07	0.21
Industrial solid waste	cu ft	2.71	1.42	0.78	0.44	0.29	0.21	0.16	0.44	0.90	0.90	0.08
Atmospheric emissions	lb	40.69	25.87	18.46	28.66	18.84	13.79	10.82	34.78	26.70	26.70	10.64
Waterborne waste	lb	7.24	5.34	4.40	5.06	4.20	3.74	3.48	3.50	6.48	6.48	1.19
Postconsumer solid waste	cu ft	21.04	10.64	5.44	17.35	9.68	5.00	2.65	75.80	30.98	30.98	0.58

Source: Midwest Research Institute.

a/ Total energy without including energy derived from burning wood wastes.

b/ Total energy after including 2.58×10^6 Btu of energy derived from burning wood wastes.

c/ Hydrocarbon feedstocks are counted as energy rather than pounds of raw materials. Wood fiber, sand, etc., are counted as pounds of raw materials.

TABLE 4

SUMMARY IMPACT DATA FOR 1,000 GALLONS OF MILK DELIVERED
(In half pint containers by type of container system)

		Milk Container Systems										
		Refillable Containers							Nonrefillable Containers			
		Glass Bottle			Plastic Bottle				Plastic Bottle	Paperboard Carton[a]	Paperboard Carton[b]	Plastic Pouch
Impact category	Units	5-Trip	10-Trip	20-Trip	5-Trip	10-Trip	20-Trip	50-Trip	1-Trip	1-Trip	1-Trip	1-Trip
Raw materials	lb	2,444.01	1,258.72	666.07	73.22	48.46	36.09	28.66	67.94	384.27	384.27	3.72
Energy	10^6 Btu	19.85	12.36	8.61	15.76	9.42	6.26	4.35	22.67	10.00	13.84	4.49
Water	10^3 gal.	3.46	2.38	1.84	3.48	3.10	2.91	2.80	2.12	4.51	4.51	0.52
Industrial solid waste	cu ft	5.64	3.10	1.83	0.85	0.56	0.41	0.32	1.14	1.39	1.39	0.16
Atmospheric emissions	lb	77.71	48.86	34.37	51.36	31.45	21.52	15.53	70.18	38.16	38.16	15.13
Waterborne waste	lb	12.54	8.82	6.96	7.86	5.79	4.76	4.14	7.42	9.60	9.60	1.70
Postconsumer solid waste	cu ft	26.14	13.34	6.94	19.87	10.80	6.26	3.54	79.56	35.53	35.53	1.37

Source: Midwest Research Institute.

a/ Total energy without including energy derived from burning wood wastes.

b/ Total energy after including 3.83×10^6 Btu of energy derived from burning wood wastes.

c/ Hydrocarbon feedstocks are counted as energy rather than pounds of raw materials. Wood fiber, sand, etc., are counted as pounds of raw materials.

1. Gallon containers: Table 1 contains the summary analysis for the one gallon containers. The information is subdivided into refillable and nonrefillable systems and according to container material and trip rate. The seven impact categories evaluated in the study are: raw materials; energy; wastewater volume; industrial solid waste; atmospheric emission; waterborne wastes; and postconsumer solid wastes. The energy category has been divided into the sources of energy, reported in million Btu, and also into the percent attributed to fossil fuels (petroleum, natural gas, and coal) and wood wastes (wood wastes burned at the papermills to produce nonpurchased energy). The detailed energy data are presented in Chapter 2.

In the raw materials category, the plastic pouch requires the smallest quantities of materials. The light weight of the container (27.8 grams) plus the fact that hydrocarbon raw materials are counted as their energy equivalents, accounts for the small material usage. The refillable glass containers require more raw materials than the other containers. The paperboard and 20-trip glass container are about equal in materials requirement. The requirements for the nonrefillable plastic container fall between the 5- and 10-trip refillable container.

The energy category shows that the refillable plastic bottles (except for the 5 trip) require the least amount of energy, followed closely by the 20-trip glass bottle and the plastic pouch. The paperboard container requires 2.58 million Btu less than the nonrefillable plastic container when the energy derived from burning wood wastes is not included in the total energy value for the paperboard system. If the wood wastes energy is included, the two containers show approximately the same energy requirements. The energy of material resource (energy equivalent of the hydrocarbon raw materials) for the nonrefillable plastic container represents 45 percent of the total system energy. The energy of material resource for the paperboard carton (attributed to the plastic coating system) is 6.1 percent of the total, including wood wastes energy. More detailed analyses of the energy category are presented in Chapter 2, Section B, and in the appendix section.

The wastewater volume category shows the plastic pouch and refillable plastic containers to have the lowest requirements. The nonrefillable plastic container shows approximately the same water usage as the 20-trip glass container.

The industrial solid waste category shows the returnable plastic bottles and the platic pouch to have the smallest quantities. These two container systems also show the smallest quantity of impacts in the waterborne waste and postconsumer solid waste categories (PCSW).

The PCSW values represent the volume occupied by the containers in a landfill. The volume retentions were assumed to be: glass (65 percent); refillable plastic (60 percent), nonrefillable plastic (60 percent); paperboard (22 percent); and the plastic pouch (0 percent). The volume occupied by the containers in a landfill in a function of the void space retained, the density of the container material and the trip rates of the containers. The plastic pouch shows the smallest landfill volume, followed by the 50-trip refillable plastic bottle and the 20-trip refillable plastic and glass bottles.

From a resource and environmental viewpoint based upon the quantity of resources required and pollutants produced, the refillable plastic and the nonrefillable plastic pouch systems show the least amounts of impacts. The primary reason for this condition is that a smaller amount of raw materials must be processed from mining through product manufacture for these than for the other types of containers per unit volume of milk delivered.

In some dairies, the refillable glass containers have been used in excess of 50 trips. The impacts for the glass container systems approach the impacts of the refillable plastic containers with trippage above 20 trips (see Chapter 4, Section B, for discussion).

The nonrefillable plastic bottle and paperboard carton are currently the most predominant milk packaging systems in the dairy market. The resource and environmental impact analysis shows that the plastic container has the least amount of impacts in the raw materials, water, industrial solid waste and waterborne wastes categories. The paperboard container shows smaller quantities of impacts for atmospheric emissions and postconsumer solid waste (and also energy when energy derived from wood wastes are not included in the total energy summation).

2. Half gallon containers: Table 3 presents the impact summaries for 1,000 gallons of milk delivered in the half gallon systems. The plastic pouch shows the least amount of impacts in six of the seven categories. However, the amounts of energy and atmospheric emissions are extremely close for the plastic pouch and the refillable plastic systems.

The impact comparisons for the half gallon systems are essentially the same as for the one gallon systems. The energydifference between the nonrefillable plastic and paperboard cartons is greater for the half gallon than the one gallon containers.

3. Half pint containers: Table 4 contains the summary impact data for 1,000 gallons of capacity in the half pint containers. The plastic pouch shows the least amount of impacts in six of the seven categories.

The impact comparisons for the half pint system are essentially the same as for the one gallon systems, except for the paperboard system. A much smaller quantity of energy is required by the half pint paperboard system when compared with the half pint nonrefillable plastic. Also, the half pint paperboard is comparable to the 10-trip refillable plastic bottle in energy use and shows less energy than the 10-trip glass bottle.

C. Analysis of Resource Inputs

This section will analyze the resource input data for 1,000 gallons of milk delivered in each one gallon container system. A separate analysis is not presented for the half gallon and half pint size (except for energy use) since the same procedure used with the gallon size can be used with the smaller sizes.

1. Raw materials: The quantities of raw materials assigned to the various systems are effected by whether the container is refillable or nonrefillable, and if the basic raw materials are hydrocarbons. For the refillable containers, the raw materials requirement is equal to the materials for one trip divided by the number of trips. The hydrocarbon raw materials for the plastic containers (and plastic coating for the paperboard container) are counted as their energy equivalents rather than pounds of raw materials. Therefore, the raw materials shown in Tables 2, 3, and 4 for the plastic containers represent process additives, and wood fiber used in the paper packaging. For the paperboard cartons, the wood fiber which becomes part of the container is counted as pounds of raw materials. The basic components of the glass system (sand, limestone, etc.) are counted as pounds of raw materials.

2. Energy: An energy analysis for the one gallon container systems (for 1,000 gallons of milk delivered is presented in Table 5 and Figure I-1.

The plastic 50-trip gallon container requires the least amount of energy at 1.56 million Btu per 1,000 gallons of milk. From Table 4 it may be seen that natural gas is the predominant energy resource for many of the container systems, with the glass systems showing the highest values, followed by the plastic pouch, the refillable plastic bottles and finally, the paperboard system at 20 percent natural gas. Wood wastes generally account for less than 4 percent of the total system energy for each system except the paperboard. The paperboard system derives 28 percent of its total energy requirement from wood wastes. The bleached kraft pulp and paperboard manufacturing process uses 37.6 percent wood wastes derived energy. The inclusion of the energy from the other processes in the paperboard system causes the 37.6 percent value to decrease to 28.2 percent for the total profile. In the paperboard systems, the total energy usage

TABLE 5

ENERGY ANALYSIS FOR 1,000 GALLONS OF MILK DELIVERED IN EACH
ONE GALLON SYSTEM (in million Btu)

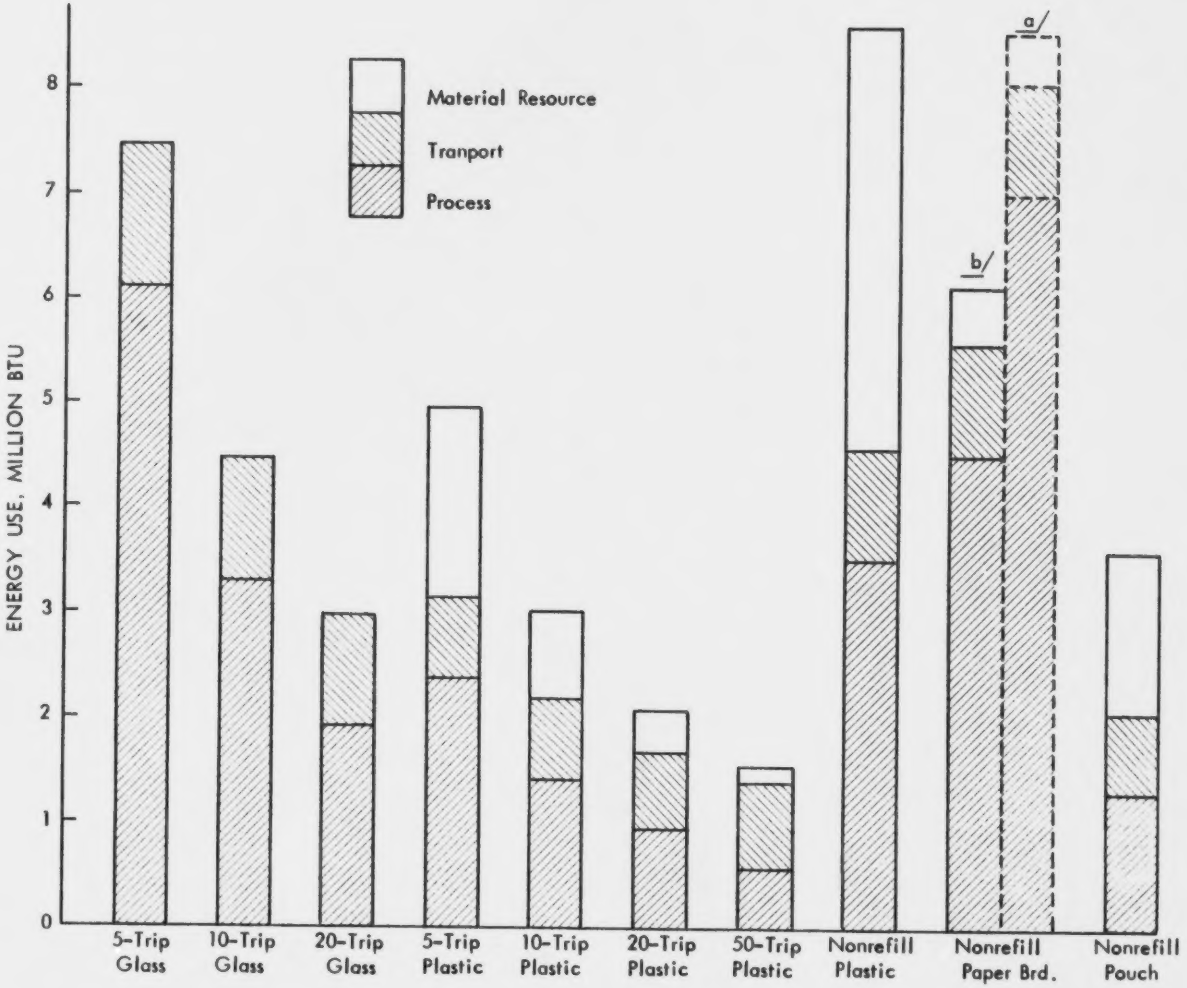
	Milk Container Systems										
	Refillable Containers							Nonrefillable Containers			
	Glass Bottle			Plastic Bottle				Plastic Bottle	Paperboard Carton[a]	Paperboard Carton[b]	Plastic Pouch
Energy category	5-Trip	10-Trip	20-Trip	5-Trip	10-Trip	20-Trip	50-Trip	1-Trip	1-Trip	1-Trip	1-Trip
Process	6.12	3.28	1.86	2.34	1.39	0.91	0.62	3.50	4.55	6.97	1.27
Transportation	1.31	1.13	1.04	0.93	0.84	0.79	0.76	1.25	1.13	1.13	0.82
Material Resource	0.00	0.00	0.00	1.71	0.86	0.43	0.17	4.03	0.53	0.53	1.50
Total[c]	7.42	4.41	2.90	4.98	3.08	2.13	1.56	8.78	6.20	8.62	3.59
Energy Source, Btu (%)											
Petroleum	1.96(26)	1.48(34)	1.25(43)	1.57(32)	1.19(39)	1.00(47)	0.89(57)	2.94(47)	2.94(34)	2.94(34)	1.25(35)
Natural gas	4.34(58)	2.29(52)	1.26(43)	2.58(52)	1.38(45)	0.78(37)	0.42(27)	5.23(70)	1.71(28)	1.71(20)	1.95(54)
Coal	0.71(10)	0.40(9)	0.25(9)	0.58(12)	0.34(11)	0.23(11)	0.16(10)	0.87(10)	1.41(23)	1.41(16)	0.31(9)
Nuclear/hydropower	0.12(2)	0.07(2)	0.04(1)	0.12(2)	0.07(2)	0.05(2)	0.03(2)	0.19(2)	0.13(2)	0.13(2)	0.07(2)
Wood wastes	0.30(4)	0.17(4)	0.11(4)	0.13(3)	0.09(3)	0.07(3)	0.06(4)	0.06(1)	0.00(0)	2.42(28)	0.01(0)
Total[c]	7.42	4.41	2.90	4.98	3.08	2.13	1.56	8.78	6.20	8.62	3.59

Source: Midwest Research Institute.

a/ Without energy derived from wood wastes.

b/ With energy derived from wood wastes.

c/ The sum of components may not equal the total due to rounding.



[a] Including Wood Wastes Energy   [b] Not Including Wood Wastes Energy

Figure 1. Summary of energy use is shown for 1,000 gallons of milk delivered in each one gallon container system.

has been adjusted (reduced) to account for the 60.92 pounds of by-products (turpentine, tall oil, etc.) that are produced per ton of air-dried pulp. Surveys by the American Paper Institute have revealed that 41.8 percent of the electricity utilized at papermill properties in 1973 were derived solely from hydropower. However, in this report all of the electrical energy used in the papermills has been charged with the impact associated with the national average mix of fossil fuels, nuclear, and hydropower required to generate and deliver the electrical energy.

Figure 2 shows a graph of the total energy requirements for 1,000 gallons of each one gallon container system. After about eight trips the efillable plastic container shows a more favorable energy usage than any of the nonrefillable containers. The refillable plastic shows less energy than the refillable glass for each trippage number. The graph demonstrates that only minor energy savings are realized after about 50 trips for the glass and plastic refillable containers. The total energy values for the container systems do not account for any energy recovery from recycling containers.

A graphical presentation of the energy requirements for the half gallon container systems is presented in Figure 3. The relative requirements for the systems are about the same, with the exception of the plastic pouch. The half gallon size pouch requires about 31 percent less energy than the gallon size (due to the absence of an outer packaging bag). Figure 3 shows that the energy requirement of the half gallon pouch compares favorably with the 35-trip plastic bottle and 50-trip glass bottle.

Energy requirements for the half pint containers are shown on Figure 4. The energy spread is now greater between the one way plastic and paperboard containers. The energy for the paperboard is about the same as a 10-trip plastic and 15-trip glass container. The glass container energy approaches the energy for the plastic pouch at high trip rates.

The total energy requirement (total profile average) for delivering milk in each container system is described in Table 6. The total energy attributed to the milk packaging segment of the dairy industry in 1973 (federal milk markets) is estimated to be 37 x 10^{12} Btu (equivalent to approximately 5 million barrels of oil). The half gallon paperboard system accounts for 41.8 percent of the milk delivered and 42.2 percent of the total energy. The paperboard systems (one gallon, half gallon, and half pint) account for 72.8 percent of the milk delivered and 78.2 percent of the total energy. A shift to the least energy-intensive system (50-trip refillable plastic bottle) would result in a total energy requirement of approximately 9 x 10^{12} Btu, representing a 76 percent decrease in total energy. The 28 x 10^{12} Btu saved would approximate 4.8 million barrels of oil.

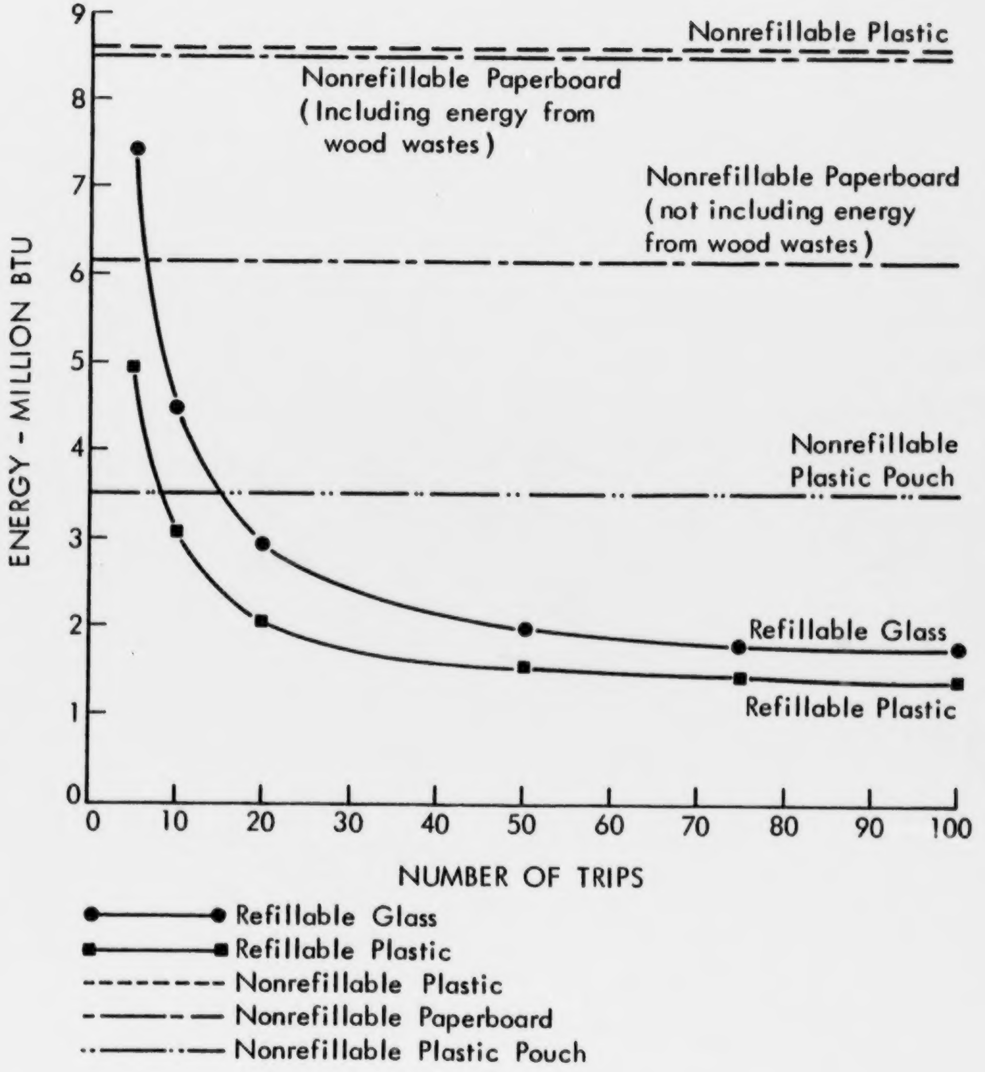


Figure 2. Energy requirements are plotted for 1,000 gallons of milk delivered in each one gallon container system.

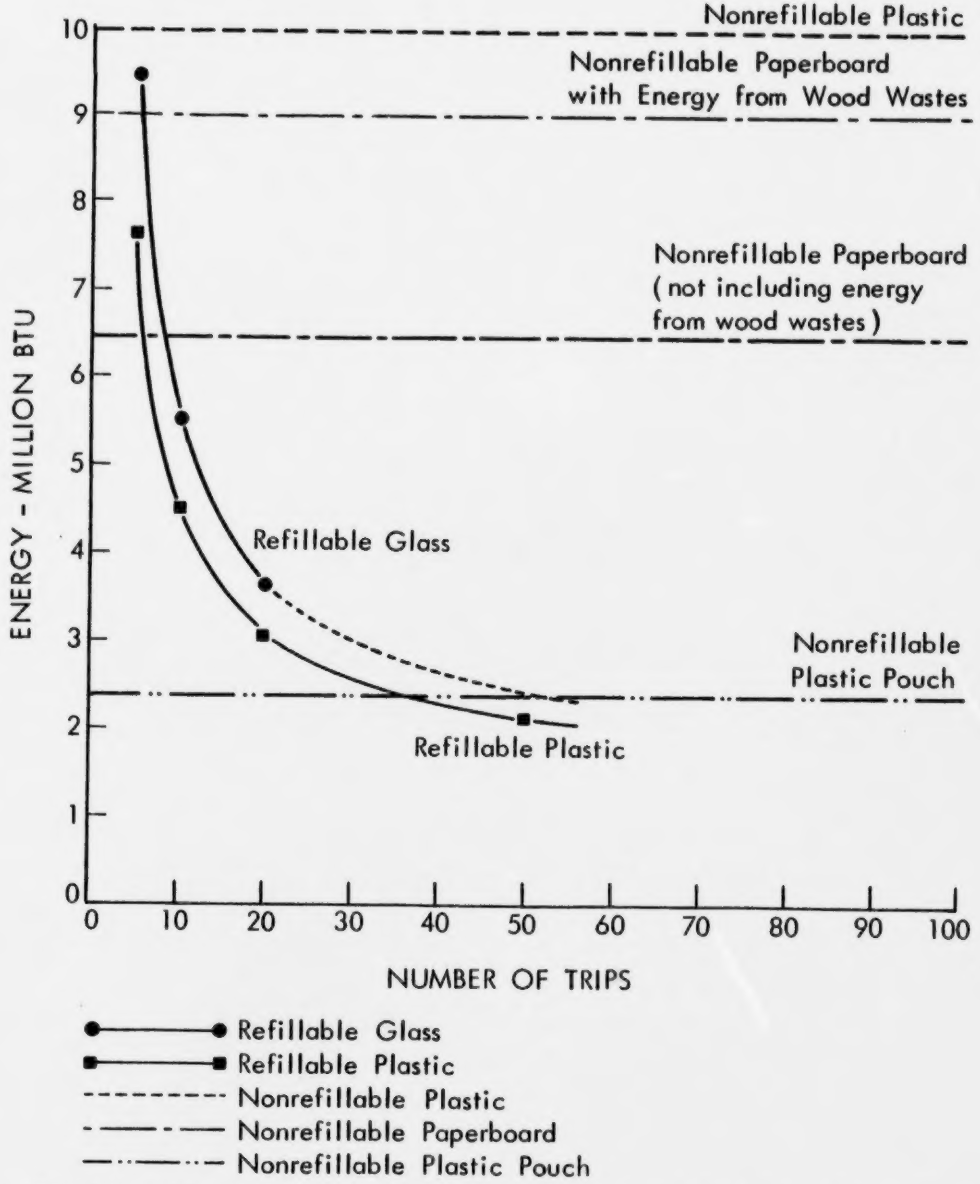


Figure 3. Energy requirements are plotted for 1,000 gallons of milk delivered in each half gallon container system.

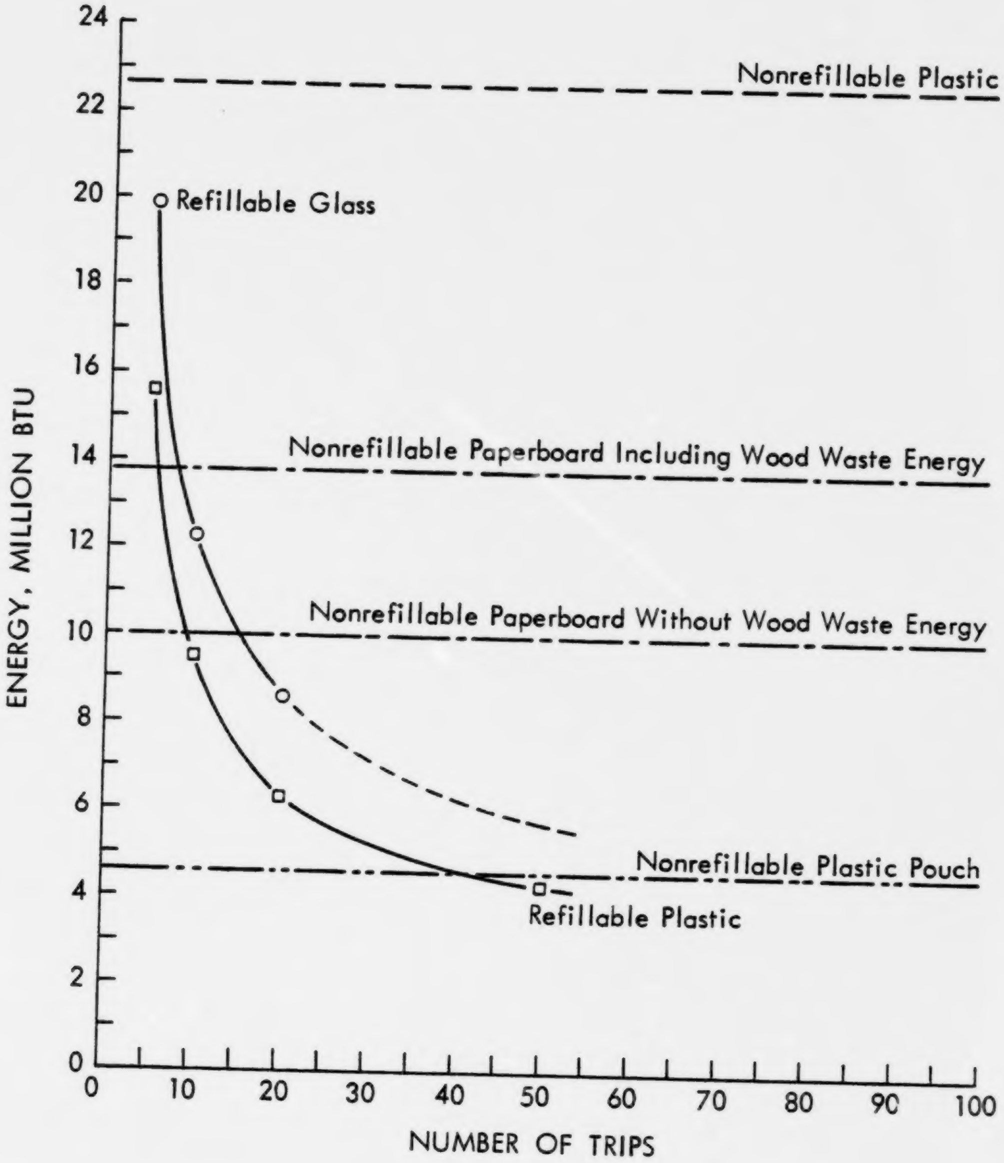


Figure 4 - Energy requirements are plotted for 1,000 gallons of milk delivered in each half pint container system

TABLE 6

MILK VOLUME DELIVERED AND TOTAL PROFILE ENERGY FOR EACH MILK CONTAINER SYSTEM
(1973 milk statistics, federal milk markets)

Container system	Container size	Volume of milk delivered, (10^3 gallons)	Percent of volume based on container size	Percent of volume based on total volume	Total energy (10^9 Btu)	Percent of total energy
Refillable glass (20-trip)	Gallon	51,386	2.8a/	1.2	149 b/	0.4
	Half gal.	102,771	5.3	2.4	380	1.0
	Half pint	1,464	0.3	0.1	12	0.0
	Totals	155,621		3.7	541	1.4
Refillable plastic (50-trip)	Gallon	117,177	6.4	2.8	182	0.5
	Half gal.	9,765	0.5	0.2	21	0.1
	Half pint	-0-	-0-	-0-	-0-	-0-
	Totals	126,942		3.0	203	0.6
Nonrefillable plastic	Gallon	771,418	41.8	18.3	6,774	18.0
	Half gal.	43,942	2.3	1.0	445	1.2
	Half pint	3,882	0.9	0.1	88	0.2
	Totals	819,242		19.4	7,307	19.4
Nonrefillable paperboard	Gallon	888,972	48.2	21.1	7,666c/	20.4
	Half gal.	1,757,390	90.7	41.6	15,879	42.2
	Half pint	424,769	97.6	10.1	5,878	15.6
	Totals	3,071,131		72.8	29,423	78.2
Nonrefillable pouch	Gallon	14,647	0.8	0.3	52	0.1
	Half gal.	24,417	1.2	0.6	58	0.2
	Half pint	4,882	1.0	0.1	22	0.1
	Totals	43,946		1.0	132	0.4
Total for all containers		4,216,882			37,606	
Total for gallon size		1,843,600			14,823	
Total for half gallon size		1,938,285			16,783	
Total for half pint size		434,997			6,000	

Source: Midwest Research Institute.

a/ ($51,386 \times 10^3$ gal. ÷ $1,843,600 \times 10^3$ gal)(100) = 2.8% of milk in 1 gallon size.

b/ $51,386 \times 10^3$ gal. x 2.90×10^6 Btu per 10^3 gal. (Table 1-2) = 149 × 10^9 Btu.

c/ Including energy derived from burning wood wastes. (Total is $5,511 \times 10^9$ Btu without wood waste for gallon, 11.352×10^9 Btu for half gallon and $4,248 \times 10^9$ for the half pint containers).

3. Wastewater volume: The quantity of water shown in the summary Tables 2, 3, and 4 represent the volume of wastewater released to the environment. The paperboard and glass systems require more water than the plastic systems.

D. Analysis of Environmental Outputs

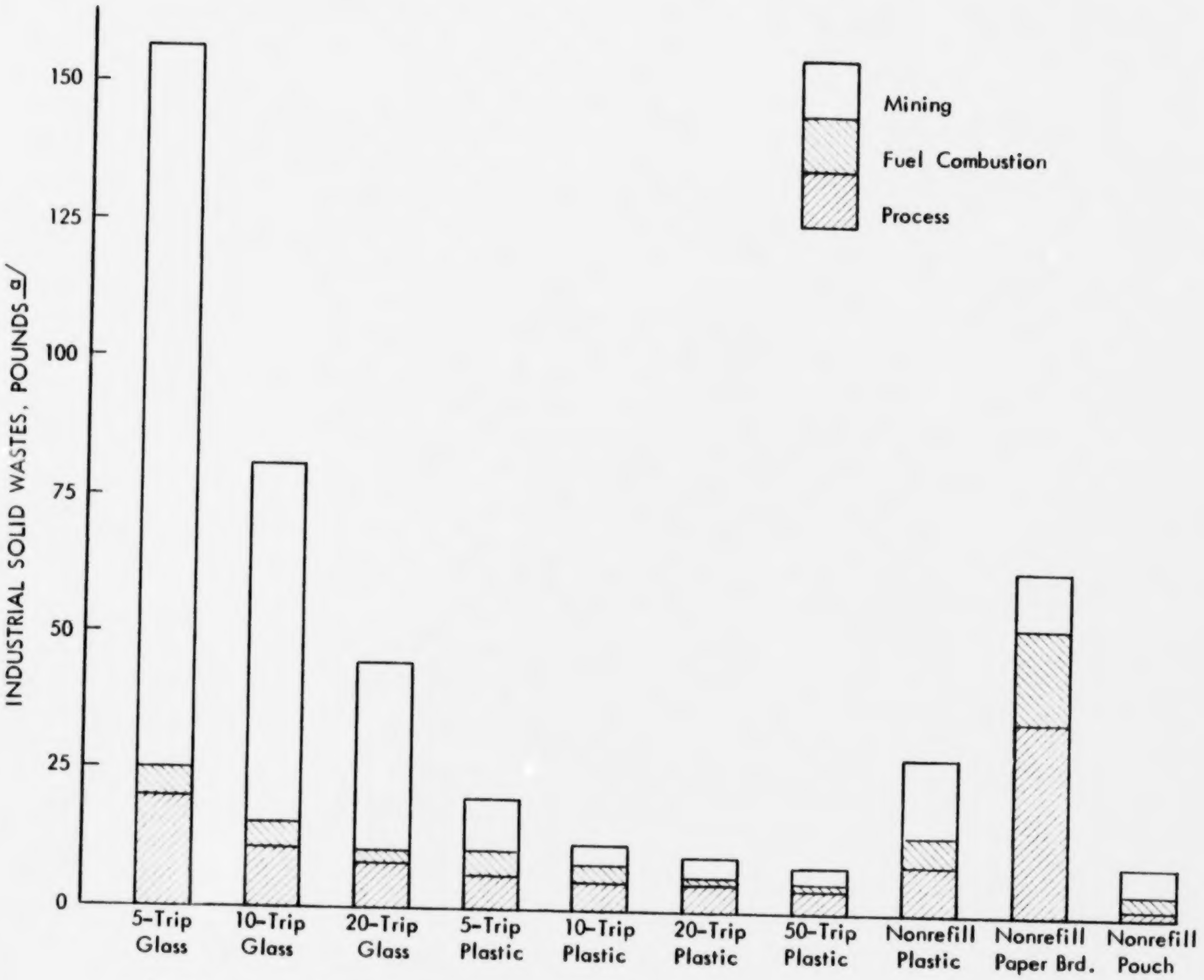
This section will analyze the environmental output data for delivering 1,000 gallons of milk in each one gallon container system. The half gallon and half pint systems can be analyzed in a similar manner.

1. Industrial solid wastes: A graph showing the contribution of process, fuel combustion, and mining wastes to the total industrial solid waste quantity is shown in Figure 5. (Table 7 contains the quantitative values of the predominant environmental outputs.) Mining wastes are the principal solid wastes for the glass systems. In the refillable plastic systems mining wastes are larger for the 5-trip plastic bottle but become second to process wastes as the trip rate increases. The mining wastes for the plastic systems come primarily from the coal mining step necessary to obtain the coal used in power generation. The solid wastes in Figure 5 are shown in pounds rather than in cubic feet, while the values in Tables 2, 3, and 4 are in cubic feet. The conversion factor used was 74.07 pounds per cubic foot.

2. Atmospheric emissions: The atmospheric emissions for the container systems are composed primarily of particles, nitrogen oxides, hydrocarbons, sulfur oxides, and carbon monoxide. The breakdown of the air pollutants is shown in Figure 6. The quantities of pollutants from the glass systems are about evenly divided. The plastic systems show very little particulate contamination. Hydrocarbons are the principal contaminant for the nonrefillable plastic container. Sulfur oxides and carbon monoxide lead the pollutants for the paperboard system.

The pollutant contained in the atmospheric emissions from the milk container systems have not been weighed to account for lesser or greater environmental and health effects. The MRI project team recognizes the fact that some pollutants are more dangerous than others. However, the methodology followed in this resource and environmental profile analysis makes no attempt to weight the pollutants according to their toxicity or other health/environmental parameters. Figure 6 and Table 7 show the quantitative breakdowns based on the predominant emissions.

3. Waterborne wastes: The primary contaminants found in the waterborne waste streams are BOD, suspended solids, dissolved solids, and alkalinity.



a/ Solid wastes values in Table 2 are expressed in cubic feet

Figure 5. Summary of industrial solid wastes are shown for 1,000 gallons of milk delivered in each one gallon container system.

TABLE 7

SUMMARY OF ENVIRONMENTAL OUTPUTS FOR 1,000 GALLONS OF MILK
DELIVERED IN EACH ONE GALLON CONTAINER SYSTEM

Impacts	Glass			Plastic						
	5-trip	10-trip	20-trip	5-trip	10-trip	20-trip	50-trip	NR-PLS	PPd	PCH
Waterborne wastes (lb)										
BOD, lb	1.12	0.68	0.47	0.54	0.40	0.33	0.28	0.43	1.44	0.20
Suspended solids, lb	1.05	0.72	0.56	0.54	0.46	0.42	0.40	0.45	2.29	0.29
Dissolved solids, lb	1.80	1.19	0.88	1.03	0.74	0.60	0.52	1.60	2.02	0.76
Alkalinity, lb	2.00	2.00	2.00	1.60	1.80	1.90	1.96	0.00	0.00	0.00
Other, lb	0.31	0.17	0.10	0.35	0.20	0.13	0.07	0.68	0.49	0.26
Total WBW, lb	6.26	4.76	4.01	4.08	3.60	3.38	3.23	3.13	6.24	1.51
Atmospheric emissions (lb)										
Particles, lb	5.96	3.10	1.67	1.37	0.80	0.52	0.35	1.68	2.97	0.58
NO_x, lb	6.34	4.07	2.94	3.84	2.67	2.08	1.73	5.88	5.28	2.74
H-C, lb	5.88	3.50	2.31	5.02	2.96	1.94	1.32	9.85	3.87	3.96
SO_x, lb	6.77	3.76	2.25	4.16	2.48	1.64	1.14	5.99	6.84	2.16
CO, lb	6.99	5.99	5.50	5.01	4.47	4.21	4.03	6.98	6.41	4.34
Other, lb	0.73	0.51	0.40	0.40	0.32	0.28	0.24	0.48	0.71	0.24
Total AE, lb	32.67	20.93	15.07	19.80	13.70	10.67	8.81	30.86	26.08	14.02
Industrial solid wastes (lb)										
Process, lb	21.05	12.76	8.62	6.82	5.64	5.05	4.70	8.36	36.73	2.42
Fuel combustion, lb	5.70	3.30	2.10	4.16	2.57	1.77	1.29	5.71	15.92	2.06
Mining, lb	130.30	65.75	33.48	8.96	5.25	3.40	2.28	13.87	10.01	5.02
Total ISW, lb	157.05	81.81	44.20	19.96	13.46	10.22	8.27	27.94	62.66	9.50
PCSW, ft^3	19.92	10.02	5.02	16.24	8.46	5.06	2.00	75.43	30.39	1.05

Source: Midwest Research Institute.

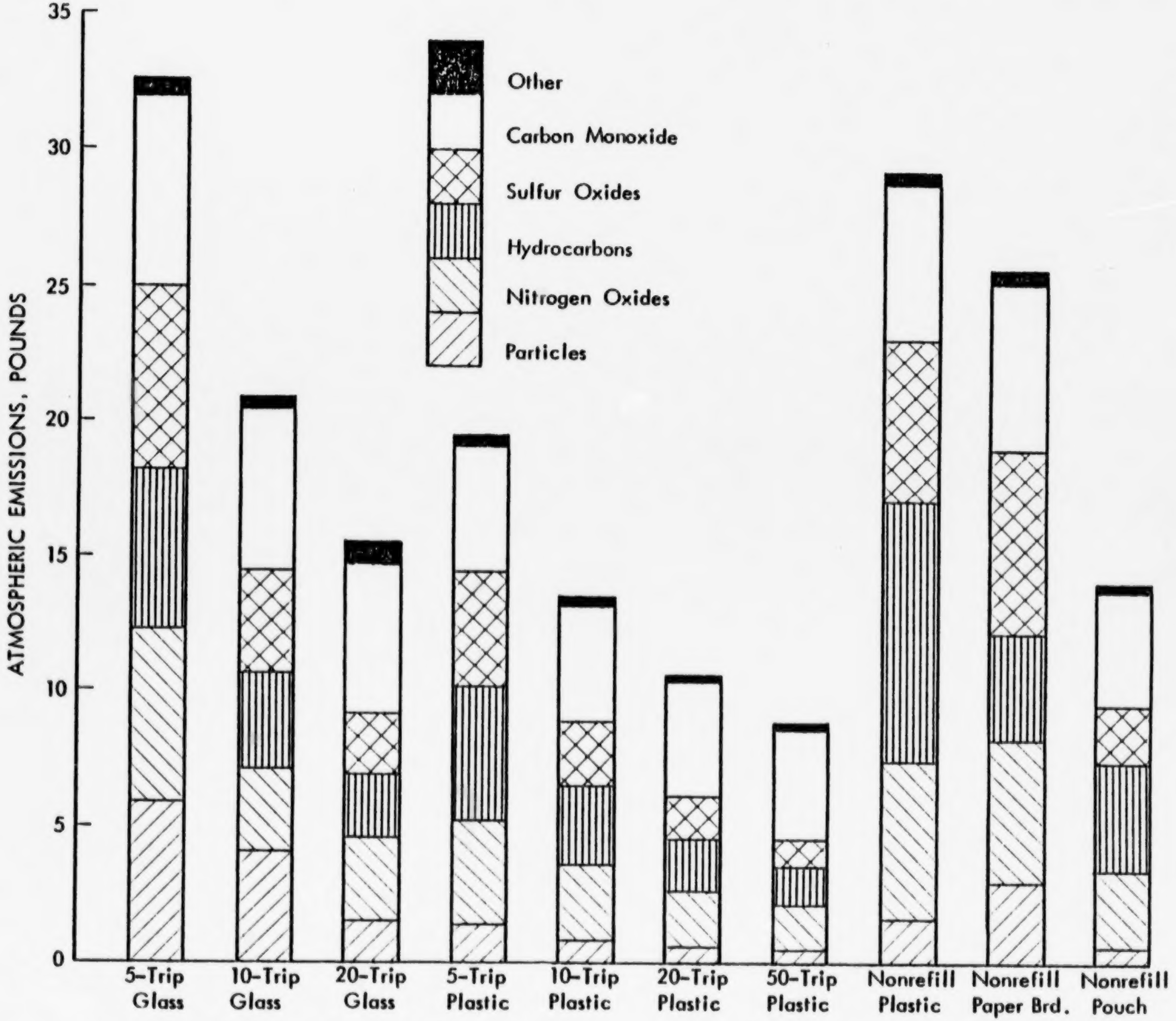


Figure 6. Summary of atmospheric emissions are shown for 1,000 gallons of milk delivered in each one gallon container system.

The refillable systems show a large percentage of alkalinity, due to the caustic discharged in the bottle washing process. The paperboard system demonstrates the highest BOD and suspended solid values among the container systems. The bleached kraft pulp and paperboard system accounts for about 65 percent of the total BOD and suspended solids values for the paper system. The dissolved solids in the plastic system result from brine disposal during crude oil and natural gas production. The "other" category for the nonrefillable plastic bottle system is made up primarily of COD and acid mine drainage effluents. Table 7 and Figure 7 contain the raw data and graphical analysis of the waterborne wastes impact category.

4. Postconsumer solid wastes (PCSW): The postconsumer solid waste category is reported in cubic feet and represents the volume which the containers would occupy in a landfill. The landfill volume and ratio of each system volume to the volume of the plastic pouch is given in Table 8. The data show that the refillable plastic systems and the plastic pouch system occupy the smallest volumes in landfill operations. The nonrefillable plastic and paperboard containers show 72 and 28 times the volume of the plastic pouch system, respectively. With the 1973 market mix (Table 9) the total volume of landfill is estimated at 78 x 10^6 cubic feet for disposal of the gallon size milk containers (91 percent landfilled). If the total market for the gallon size had used the plastic pouch, the total volume of landfill would be an estimated 1.76 x 10^6 cubic feet, or a decrease of 98 percent in landfill volume.

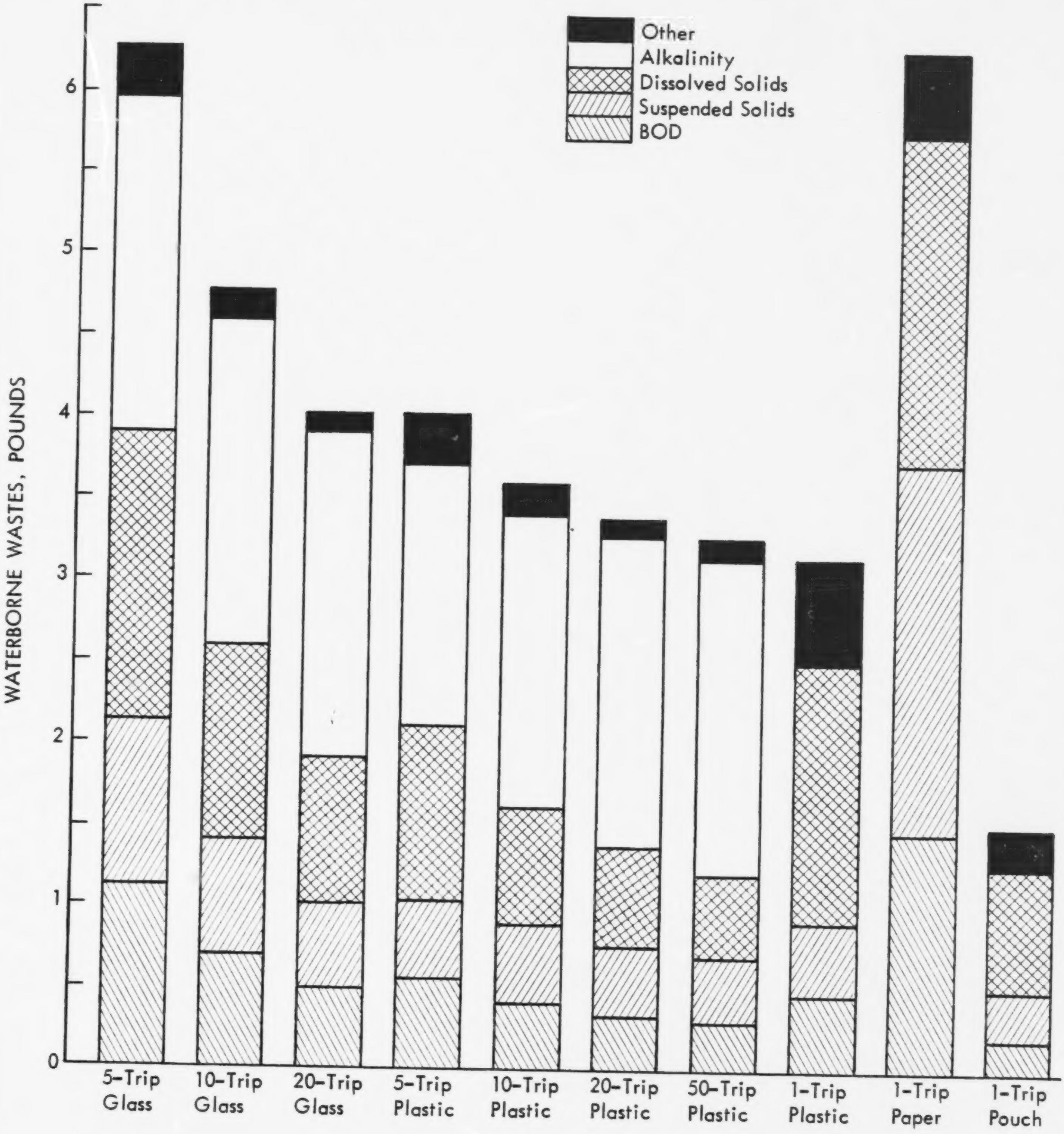


Figure 7 - Summary of waterborne wastes are shown for 1,000 gallons of milk delivered in each one gallon container system

TABLE 8

POSTCONSUMER SOLID WASTE FOR 1,000 GALLONS OF MILK DELIVERED IN EACH ONE GALLON CONTAINER SYSTEM

Container system	Volume in landfill (ft^3)	Ratio of system volume to plastic pouch system volume
5-trip glass	19.92	18.97
10-trip glass	10.02	9.54
20-trip glass	5.02	4.78
5-trip plastic	16.24	15.47
10-trip plastic	8.46	8.06
20-trip plastic	5.06	4.82
50-trip plastic	2.00	1.90
Nonrefillable plastic	75.43	71.84
Nonrefillable paperboard	30.39	28.94
Nonrefillable plastic pouch	1.05	1.00

Source: Midwest Research Institute.

TABLE 9

MILK VOLUME DELIVERED AND POSTCONSUMER SOLID WASTE FOR 1973
(federal milk market)

Container system	Container size	Volume of milk delivered (10^3 gallons)	Percent based on container size	Estimated volume PCSW (10^3 ft^3)
Refillable glass (20-trip)	Gallon	51,386	2.8[a]	258[b]
	Half gal.	102,771	5.3	559
	Half pint	1,464	0.3	10
	Total	155,621	3.7 (RET-GLS %)	827
Refillable plastic (50-trip)	Gallon	117,177	6.4	234
	Half gal.	9,765	0.5	26
	Half pint	-0-	-0-	0
	Total	126,942	3.0 (RET-PLS %)	260
Nonrefillable plastic	Gallon	771,418	41.8	58,188
	Half gal.	43,942	2.3	3,330
	Half pint	3,882	0.9	309
	Total	819,242	19.4 (NR-PLS %)	61,827
Nonrefillable paperboard	Gallon	888,972	48.2	27,015
	Half gal.	1,757,390	90.7	54,443
	Half pint	424,769	97.6	15,092
	Total	3,071,131	72.8 (PB %)	96,550
Nonrefillable plastic pouch	Gallon	14,647	0.8	15
	Half gal.	24,417	1.2	14
	Half pint	4,882	1.0	7
	Total	43,946	1.0 (PCM %)	36

Source: Midwest Research Institute.

a/ (51,386,000 gal. ÷ 1,843,600,000 gal. for all gallon size containers) x 100 = 2.8 percent of gallon size containers.

b/ 51,386,000 gal x 5.02 ft^3 per 1,000 gal of the 20-trip glass (Table I-2) = 258,000 ft^3 landfill volume.

CHAPTER 4

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS OF EACH CONTAINER SYSTEM

A. Description of REPA Technique

In the past, most environmental analyses have focused on a single pollution category such as the air pollution caused by industry A or the water pollution and solid wastes associated with industry B. The pollution reported for these industries usually refers to one manufacturing step, at a single geographical location. This type of approach will generally account for less than 25 percent of the total impacts associated with a product. Accounting for a product's total environmental impact requires a systems approach, beginning at the point of raw material extraction and ending with the final disposal of the product. The systems approach quantifies the use of natural resources and the resulting pollution to the environment.

The purpose of a resource and environmental profile analysis (REPA) is to measure the resource and environmental impacts at each stage of a product's life, and then condense the data into several basic impact categories which can be used to determine a product's overall impact relative to other products. The results of a REPA analysis must be used with the understanding that the product may have much smaller impacts than its competitor, and still be a resource or environmental villain. To ascertain a product's absolute impact status would require a rigorous treatment of impact data, environmental desires or regulation, and the social and economic aspects, etc.

Two broad classes of environmental impacts can be discerned: (1) quantifiable impacts; and (2) those of a more subjective, qualitative nature. The former category includes impacts which can be measured, such as kilowatt-hours of energy and pounds of air pollutants, for various manufacturing processes. The latter category includes impacts for which hard data do not exist. For example, it is impossible to assign precise numerical measures of aesthetic blight caused by mining activities. Another impact of the latter type is that for which some data exist, but are of very poor quality. Examples of this are relative environmental damage of solid waste disposal of various products, or the relative environmental damage of various air pollutants or of various water pollutants. This study is confined to the determination of the quantitative impacts only. Qualitative aspects, although referred to from time to time in this study, are not part of this analysis.

1. Basic approach: Much of the effort expended in this study went into determining the quantifiable impacts of manufacture. The term "manufacture" is used throughout this report in a general sense--it includes those activities associated with materials from the time they are extracted from the earth as raw materials to the point where they are returned to the earth as wastes, including all transportation links in the processing sequence. A summary of the impacts documented is shown in Figure 8.

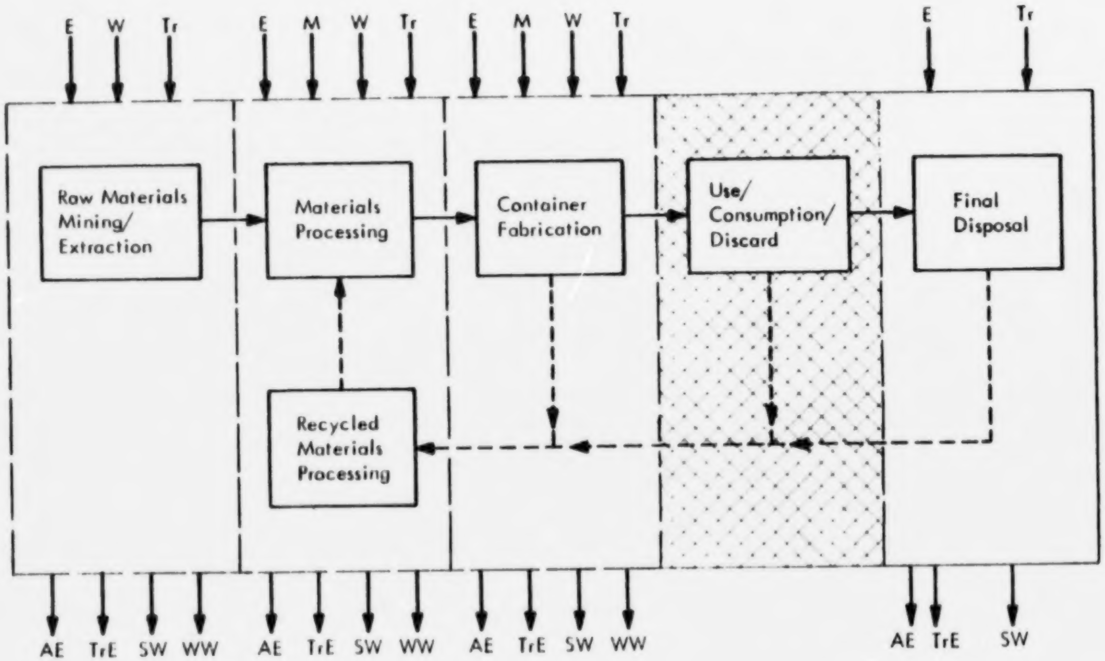
For each process and subprocess, a set of seven basic impact categories was established. These are described below:

Raw materials: The quantity and type of virgin raw materials input to each operation were calculated in terms of a given product output. Materials not intended to become part of the finished product, such as cooling water and fuels, were excluded from raw materials. Other raw materials, such as additives, which aggregate to less than 5 percent of the total weight of the finished container were included in this category by reporting their finished product weight. Each raw material was counted only one time--when it became a part of the product or entered the process as a solvent, catalyst, etc.

No attempt was made to define a relative weighting of the various virgin materials based on availability or scarcity. The possibility exists for developing such a scheme based on the projected reserves or scarcity of recoverable raw materials still in the earth. However, examination of the many raw materials consumed by these product systems shows that none of these materials are in short supply. The materials included are: limestone, salt, sand, soda ash, feldspar, and wood fiber. Crude oil and natural gas are in relatively short supply, but they have been classified as energy resources, not as material resources. Wood fiber is consumed, but timber growth exceeds the timber cut annually at present in this country. Thus it is not a "short" material.

Energy: The energy used by each operation, including transportation, for a given product output was reported. Process energy used by the actual manufacturing operations was employed. That used for space heating of buildings and other miscellaneous categories was excluded wherever possible. Energy content of organic raw materials was also included in energy summations. The second-order energy necessary to extract, process and transport fuels is included, as well as the heating value of the specific fuels used in a system. In this report, the Btu equivalent used for a unit of the following types of energy is kilowatt-hour - 10,720 Btu, standard cubic foot natural gas - 1,030 Btu, 1 pound of steam - 1,600 Btu, coal - 13,300 Btu per pound.

Water volume: The volume of wastewater per unit of product output from each operation was reported.


E
W
Tr
M
Raw Materials Mining/ Extraction
Materials Processing
Recycled Materials Processing
Container Fabrication
Use/ Consumption/ Discard
Final Disposal
AE
TrE
SW
WW

SUMMARY OF INPUT/OUTPUT CATEGORIES

INPUT

E = Energy (in all forms)

M = Virgin Materials (consumed and unconsumed)

W = Water

Tr = Transportation to Next Operation
(including all modes, all fuels in each mode)

OUTPUT

AE = Atmospheric Emissions

TrE = Transportation Effluents (for each fuel type)

SW = Solid Wastes

WW = Waterborne Wastes

Figure 8. Summary of environmental impacts are shown for container manufacture.

Industrial solid wastes: The volume of solid waste per unit of product output which must be landfilled or disposed of in some other way was determined. Three categories were measured: process losses, fuel combustion residues (ashes) and mining wastes. The first category--process discards--includes solids resulting from air pollution control and trim and waste materials from manufacturing operations. Fuel combustion residues are ash generated by coal combustion. Mining wastes are primarily materials discarded due to raw ore processing and do not include overburden.

Atmospheric emissions: This category includes only those emissions generally considered to be pollutants, expressed in pounds per unit of product output. Typical pollutants considered for each operation are: particulates, nitrogen oxides, hydrocarbons, sulfur oxides, carbon monoxide, aldehydes, other organics, chlorine, odorous sulfur compounds, ammonia, hydrogen fluoride, lead and mercury. The amounts reported represent actual discharges into the atmosphere after existing emission controls have been applied. All such atmospheric emissions were treated as being of equal weight, and no attempt was made to determine the relative environmental damage of each of these pollutants. However, we do recognize that there are differences in the relative harm caused by air pollutants.

Waterborne wastes: This category includes the water pollutants from each operation expressed in pounds per unit product output. These are effluents after wastewater treatment has been applied and represent discharges into receiving waters. Twenty-three specific pollutants are included--BOD, COD, suspended solids, dissolved solids (oil field brine), oil, fluorides, phenol, sulfides, acid, alkalinity, metal ions, ammonia, cyanide, and others. Some factors such as turbidity and heat were not included because there was no acceptable way to quantify their impacts.

Postconsumer solid wastes: The volume of solid wastes generated by disposing of the container was determined. This is the solid waste which most likely would be discarded into municipal solid waste streams. It was assumed that 9 percent would be incinerated and 91 percent would be landfilled.

The first step in the REPA analysis is to determine the raw values for each of the above seven categories attributed to the production of some unit quantity of a product. The data in these categories are used to determine a product's resource and environmental impact relative to another product.

2. Organic raw materials--unique considerations: A unique situation exists for products utilizing organic raw materials such as wood, crude oil and natural gas. These materials have alternative uses as feedstocks for material goods such as paper or plastic products, or as fuels for energy. In assessing resource depletion, then, use of organic materials can be considered as depleting either material resources or energy resources.

In the first option, the organic materials intended to become part of a finished product are simply measured in pounds and treated as any mineral resource. In the second option, the energy equivalent of the pounds of hydrocarbon feedstocks used is added to the energy required to process the materials. The pounds of hydrocarbons used are not added to the raw materials category.

Another consideration regarding the fuel value of synthetic materials is that finished plastic and paper containers are a potential fuel even after they have been used and discarded. Thus, if the solid waste stream is incinerated and energy recovered, part of the original fuel value of the natural gas and wood fiber is reclaimed.

Because of the importance of energy considerations, a strong case can be made for the second option, which counts hydrocarbon raw materials as an energy resource rather than as a material resource. This treatment reflects more accurately the primary environmental concern of the plastics industry, which is the consumption of energy reserves in the form of natural gas and petroleum. These fuels at present, and in the near future, are in short supply to a greater extent than any other major natural resource. As mentioned earlier, the material resources considered in this study such as limestone and sand are much more abundant than natural gas and petroleum. Counting petroleum and natural gas use as equivalent on a pound-for-pound basis with limestone would not give as true an environmental picture as counting the energy value of these materials. Because essentially no recovery of the intrinsic fuel value of finished plastic products is practiced at present, the impact on the nation's energy reserves due to plastics manufacture is the sum of the process energy required for plastics manufacture, and the inherent fuel value of the organic materials consumed. Thus, treating hydrocarbon raw material as an energy input, rather than as a physical quantity of material, places the comparison of competitive container systems on a more logical basis.

3. Methodology: The general approach used to carry out the calculations for the quantitative comparison follows a system approach. All processes and subprocesses were first considered to be separate, and independent. For each process, a standard unit such as 1,000 pounds of output was used as a basis for calculations. A complete materials

balance was first determined. If marketable coproducts or by-products were produced, the material inputs were adjusted to reflect only the input attributable to the output product of interest.

To illustrate this point, consider a hypothetical manufacturing process that produces 1,000 pounds of product A in which we are interested. At the same time, it produces 500 pounds of coproduct B and 100 pounds of waste in the form of air emissions, water pollution, and solid waste. The total input of raw materials is 1,600 pounds as shown in Figure 9. An energy input of 3 x 10^9 Btu is assumed for this example. The output is 1,000 pounds of product A and 500 pounds of product B.

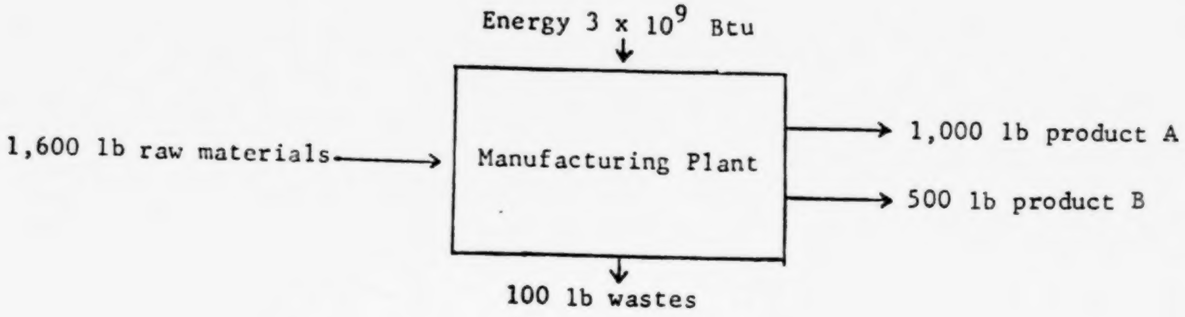
A 500-pound credit has been applied to the input materials because we are not interested in product B. This reduces the input from 1,600 pounds to 1,100 pounds. In addition, because product B is one-third of the product output of the process by weight, one-third of the wastes, or 33 pounds, is attributed to product B; a new waste figure of 67 pounds (100 pounds - 33 pounds = 67 pounds) results. Thus, the raw material input value for product A is 1,067 pounds (1,100 pounds - 33 pounds = 1,067 pounds).

Once the raw impacts for the production of 1,000 pounds of each process have been determined, a master flow chart can be established. This chart will show the pounds of each process necessary to produce 1,000 pounds of the container systems being studied. At this point, the raw data for a product system can be processed by the computer and combined with transportation, postconsumer solid waste, and secondary impacts to provide calculations showing the resource environmental profile for the system. The calculated impact data can be used alone to demonstrate the quantities of each impact category. Summary tables showing the total impacts for the processes and systems are provided and appear in the Appendix.

4. Assumptions and limitations: An important part of any study concerns the assumptions that must be made since some assumptions are always necessary to limit a study of reasonable scope. It is important for the reader to know what guidelines have been made in order for him to understand fully the scope and applicability of the study.

In the course of this research, the following assumptions were made:

Data sources: An attempt was made in every case to obtain data which were "typical" and which could be verified in the open literature. Extensive use was made of government agencies and publications, technical associations and open literature sources. National average data were used where possible. Certain sets of data involved proprietary processes so that information was submitted to us on a confidential basis. However, data in the public domain were used whenever possible.


Energy 3 x 10^9 Btu
1,600 lb raw materials
Manufacturing Plant
1,000 lb product A
500 lb product B
100 lb wastes

For analysis purposes, a new flow diagram would be established as shown below.

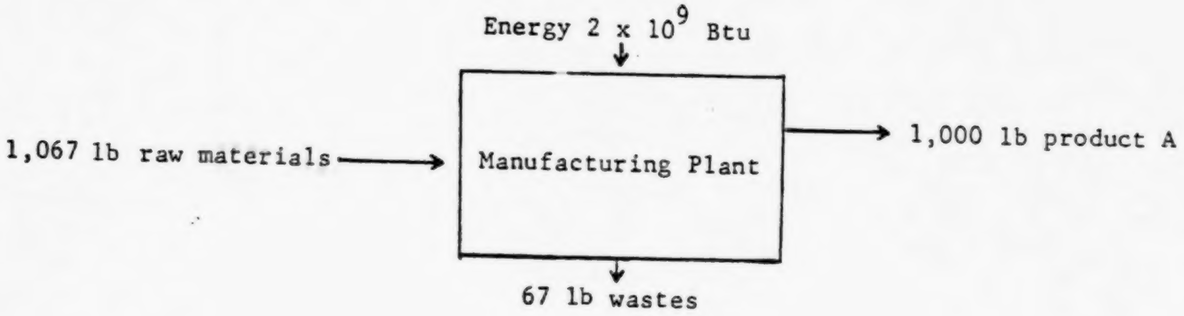

Energy 2 x 10^9 Btu
1,067 lb raw materials
Manufacturing Plant
1,000 lb product A
67 lb wastes

Figure 9. Diagram illustrates coproduct credits.

Geographic scope: The "environment" was defined as the environment of the world. However, impacts occurring outside this country are not well documented, so U.S. data were used to calculate foreign impacts.

Secondary impacts: Impacts resulting from extraction, processing and transporting fuels are secondary impacts and were considered as well as the primary impacts of the fuel combustion. However, secondary impacts resulting from effects such as manufacturing the capital equipment used in container manufacture are small per unit output and can be excluded without significant error.

Small quantities of materials: The impacts associated with materials which aggregate to less than 5 percent by weight of the container were not included. The materials are simply counted as pounds of raw materials. The list of materials which comprise the "less than 5 percent" category was examined to insure that no known "high environmental impact" materials were excluded from the analysis.

Electricity: Electrical energy is considered from the point of view of its impact on the total energy resources of the nation. A national average energy expenditure of 10,720 Btu is required for each kilowatt-hour of electricity make available to the public. Hence, this conversion factor is used rather than the direct use conversion factor of 3,413 Btu per kilowatt-hour. The impacts from mining or extraction of these fuels were included in the analysis.

Usage of scrap materials: Environmental impacts of scrap are considered to be only those impacts incurred after the scrap is discarded from the manufacturing site. Usually this includes only transportation and scrap processing steps. The environmental impact of manufacture of the material which subsequently becomes scrap is allocated to the prime product.

Point sources of pollution: The burden on specific ecosystems was not considered, i.e., at specific point sources or geographic locations. It was assumed the operations took effect on the environment everywhere, not just where specific manufacturing operations are presently located.

Availability of data: Many industrial plants do not keep records in sufficient detail to determine the data in the desired form for a REPA study. For instance, if pollutant emission data are needed for a specific subprocess in a plant, that information may not be available. The plant may have data only for several combined processes or the entire plant. In this event, allocation must be used for data on the particular processes of interest. As the concept of resource and environmental profile studies gains acceptance, it is likely that more industries will make an effort to collect these types of data from their own operations and on a unit process basis. Engineering calculations of materials balances for subprocesses were used in some instances where actual operating data were not available.

Effluent data: EPA 1977 guidelines were used where possible for air, water and solid waste discharges to the environment. If actual discharges are less than the guidelines, then the smaller values are used. For example some of the processes in the paperboard profile show impacts smaller than the 1977 guidelines. The application of future standards has the effect of shifting effluents from one category into others. It does not usually add or subtract from total amounts of effluents. For example, air pollution control usually removes air pollutants from air and they are then discharged to water bodies or become solid waste. Thus, reducing air pollution from a plant will usually increase the water pollutant and/or solid waste discharge.

Consumer impacts: Impacts related to consumer activities such as transporting the milk home from the retail store were not included. We have assumed that trips to retail stores are necessary for other reasons and should not be attributed to the container systems.

B. Refillable Glass Containers

1. Overview: Figures 10, 11 and 12 are flow diagrams for the refillable glass milk bottle systems. The material inputs required are primarily sand, limestone, natural soda ash and feldspar. These materials are combined at a glass plant to manufacture refillable milk bottles. The refillable milk bottle system consists of the manufacture of glass bottles, along with washing, filling, delivering and return of used bottles. Refillable glass bottles can be used 100 or more times on the average before they have to be discarded for structural reasons. However, the bottles become scuffed during handling and use and frequently are discarded at the dairy after several trips because of appearance. The actual trippage achieved by bottles varies widely from dairy to dairy, but most fall in a range of 5 to 20 trips.

2. Glass manufacture: A summary of the impacts of manufacture of 1,000 pounds of glass bottles is given in Table 10. Eight separate processes are shown in this table, but two of these processes, glass container manufacture and corrugated package manufacture, together represent the majority of impacts in five of the seven impact categories. They do not lead in two impact categories of postconsumer solid waste (discard of the container itself) and industrial solid waste. The latter category is dominated by feldspar mining, from which considerable mining wastes are generated.

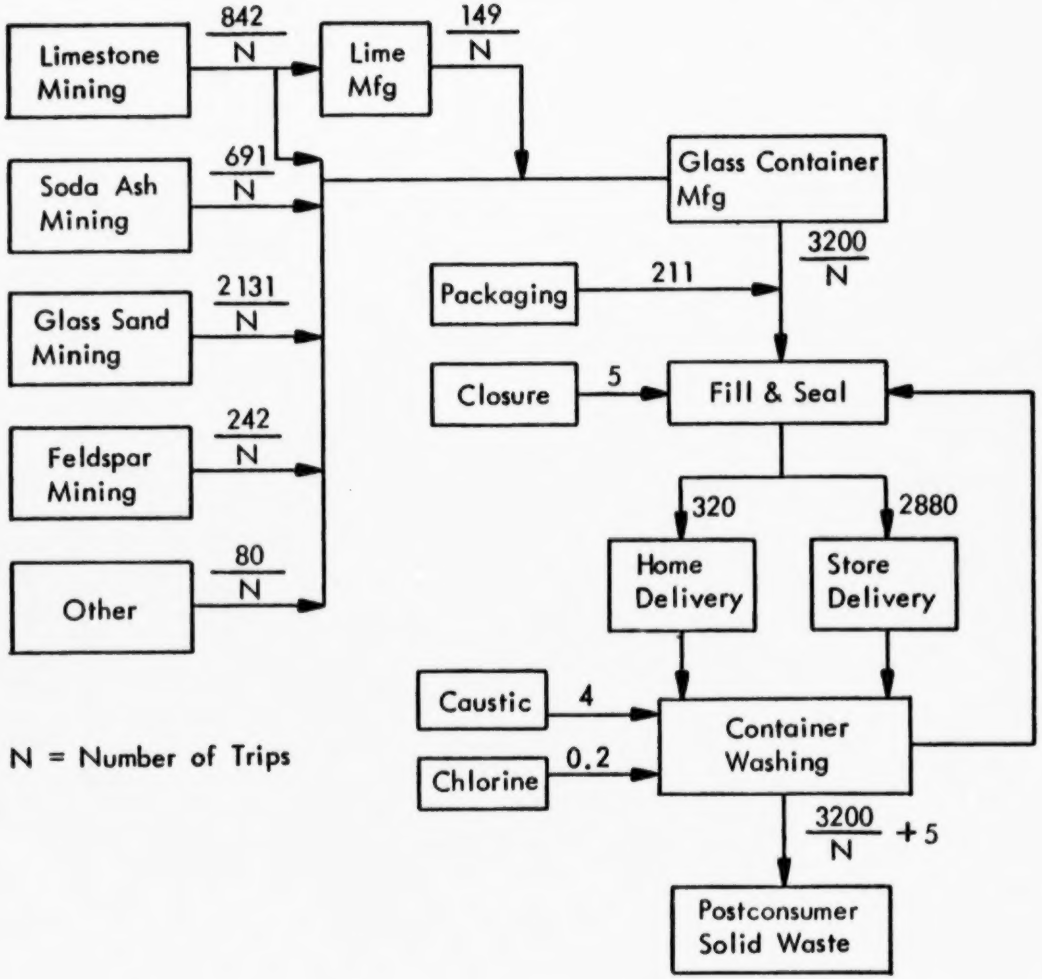

Limestone Mining
842/N
Lime Mfg
149/N
Soda Ash Mining
691/N
Glass Sand Mining
2131/N
Feldspar Mining
242/N
Other
80/N
Glass Container Mfg
3200/N
Packaging
211
Closure
5
Fill & Seal
320
2880
Home Delivery
Store Delivery
Caustic
4
Chlorine
0.2
Container Washing
3200/N + 5
Postconsumer Solid Waste
N = Number of Trips

Figure 10. Flow diagram shows the delivery of 1,000 gallons of milk in refillable glass gallon containers (in pounds).

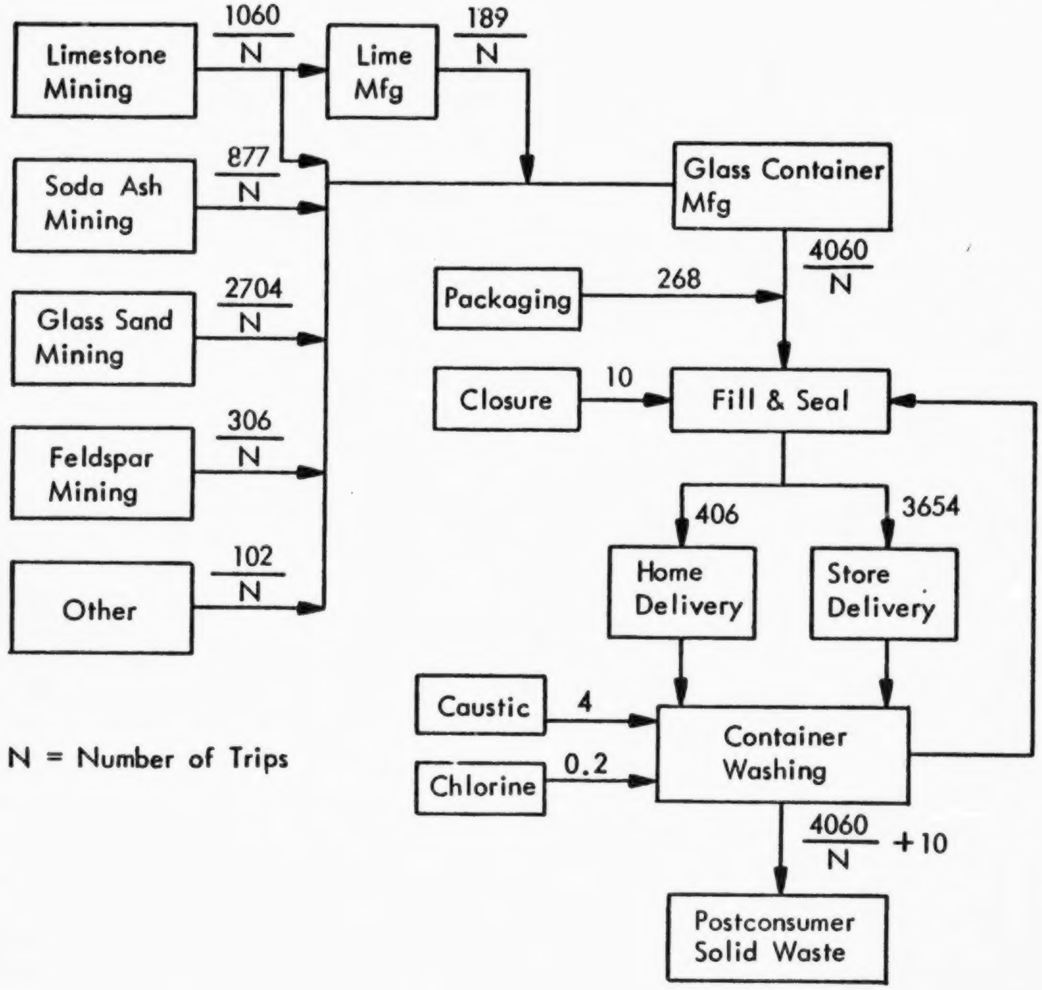

Limestone Mining
1060/N
Lime Mfg
189/N
Soda Ash Mining
877/N
Glass Sand Mining
2704/N
Feldspar Mining
306/N
Other
102/N
Glass Container Mfg
4060/N
Packaging
268
Closure
10
Fill & Seal
406
3654
Home Delivery
Store Delivery
Caustic
4
Chlorine
0.2
Container Washing
4060/N +10
Postconsumer Solid Waste
N = Number of Trips

Figure 11. Flow diagram shows the delivery of 1,000 gallons of milk in refillable half gallon glass containers (in pounds).

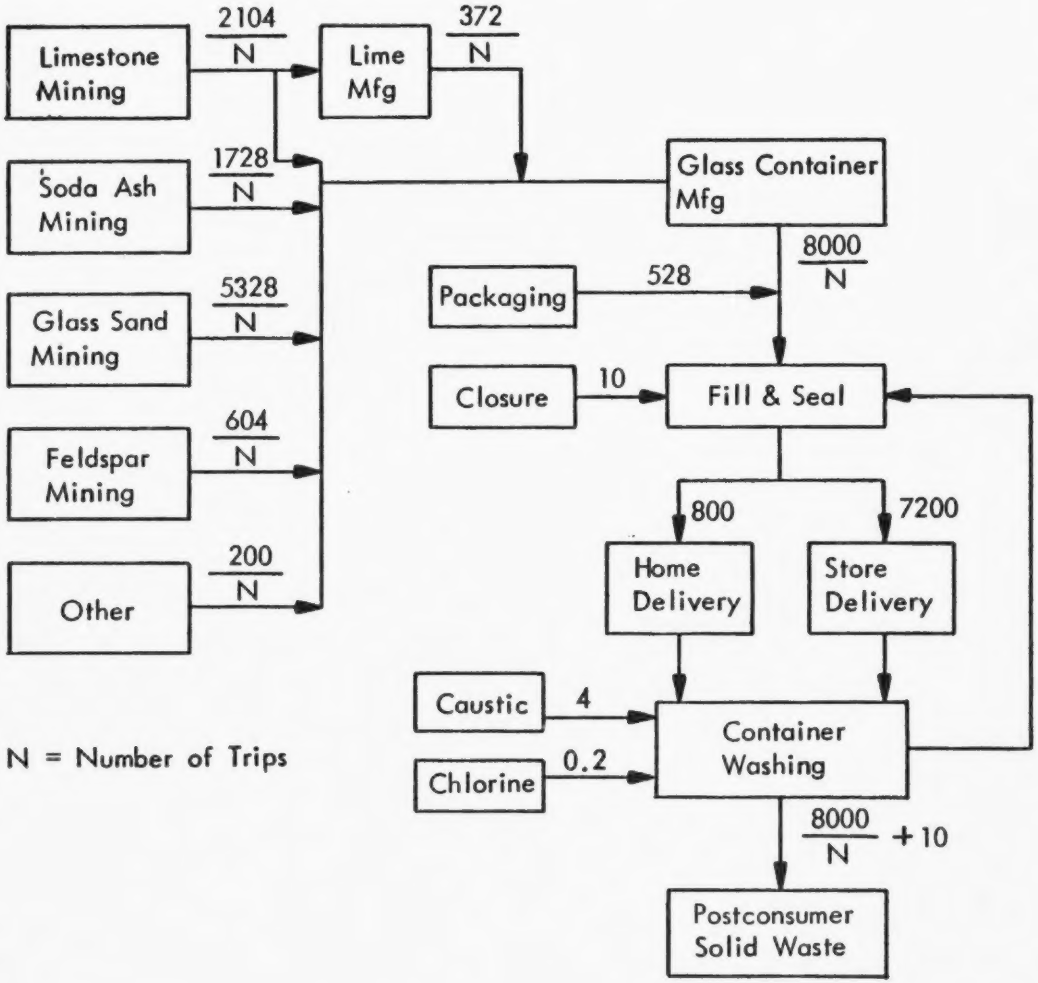

Limestone Mining
2104/N
Lime Mfg
372/N
Soda Ash Mining
1728/N
Glass Sand Mining
5328/N
Feldspar Mining
604/N
Other
200/N
Glass Container Mfg
8000/N
Packaging
528
Closure
10
Fill & Seal
800
7200
Home Delivery
Store Delivery
Caustic
4
Chlorine
0.2
Container Washing
8000/N + 10
Postconsumer Solid Waste
N = Number of Trips

Figure 12. Flow diagram shows the delivery of 1,000 gallons of milk in refillable half pint glass containers (in pounds).

In the energy category, glass container manufacture accounts for 72 percent of the total system energy, while corrugated packaging is in second place with 11 percent of the total. Together they represent 83 percent of the total energy required for 1,000 pounds of glass bottles. Percent values are shown under "Index of Environmental Impacts" in Table 10.

3. Components of total refillable glass system: A summary of the impacts resulting from delivery of 1,000 gallons of milk in one gallon glass jugs, achieving an average reuse of 20 trips per bottle is given in Table 11. This table is presented as an example of a total glass container system to show the relationship between the various component processes. Tables 12 and 13 contain the impact summaries for the half gallon and half pint glass container systems.

No single process dominates by producing more impacts in all of the impact categories. Table 14 shows that the glass bottle manufacture step produces higher impacts in three categories and is tied in a fourth; filling and washing containers creates higher impacts in one category and is tied in a second; and milk distribution and waste disposal each lead in one category.

In the energy requirements category, glass bottle manufacture accounts for 1.42×10^6 Btu of the system total of 2.903×10^6 Btu or 49 percent of its total. The distribution of milk is in second place, accounting for 0.948×10^6 Btu, or 33 percent of the total. Together, these two steps account for 82 percent of the total energy.

An important factor is the prominent position of container manufacture in the total refillable bottle system. In previous work done for EPA on beverage containers, refillable bottles show a rapid decline in importance for the container manufacture step as trippage increases, so that even at five trips, glass beverage container manufacture accounts for only one quarter of the total system energy, and declines for higher trip rates (Ref. 21). However, for glass milk containers, glass manufacture is a more prominent feature of the refillable container impact profiles than is the case for beverage bottles.

TABLE 10

SUMMARY OF IMPACTS FOR MANUFACTURE OF 1,000 POUNDS OF GLASS BOTTLES

		SAND MINING 666 LB LB	LIMESTON MINING 263 LB	FELDSPAR MINING 75 LB	NAT SODA ASH MINING 216 LB	LIME MANUF 46 LB	GLASS CONTAIN MANUF 1000 LB	CORRUGAT PACKAGE 66 LB	TRANSPOR	TOTAL
INPUTS TO SYSTEMS										
NAME	UNITS									
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	46.002	0.000	46.002
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	186.000	263.000	0.000	0.000	449.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	666.000	0.000	0.000	666.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	216.000	0.000	0.000	216.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	75.000	0.000	0.000	75.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.035	.008	.027	0.000	.004	.575	.303	.431	1.393
ENERGY SOURCE NAT GAS	MILL BTU	.156	.002	.007	.680	.037	5.354	.191	0.000	6.436
ENERGY SOURCE COAL	MILL BTU	.076	.002	.011	0.000	.050	.652	.183	0.000	.973
ENERGY SOURCE MISC	MILL BTU	.006	.000	.002	0.000	.001	.147	0.000	0.000	.156
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	.375	0.000	.375
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	0.000	0.000	0.000	25.000	4.620	0.000	29.620
ENERGY PROCESS	MIL BTU	.278	.011	.025	.680	.091	6.728	1.057	0.000	8.471
ENERGY TRANSPORT	MIL BTU	.004	.001	.023	0.000	.000	0.000	.006	.431	.665
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATER VOLUME	THOU GAL	.604	.012	.170	.141	.007	.372	.021	.025	1.356
OUTPUTS FROM SYSTEMS										
NAME	UNITS									
SOLID WASTES PROCESS	POUND	0.000	0.000	0.000	0.000	8.463	13.000	4.422	0.000	25.665
SOLID WASTES FUEL COMB	POUND	.249	.011	.070	0.000	.127	3.903	2.993	.100	7.473
SOLID WASTES MINING	POUND	1.124	.028	172.676	12.960	.715	10.450	2.608	0.000	201.711
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	.125	1.713	.579	1.093	.830	1.960	2.577	.056	8.936
ATMOS NITROGEN OXIDES	POUND	.189	.009	.083	.358	.060	4.277	1.071	.944	6.991
ATMOS HYDROCARBONS	POUND	.193	.006	.025	.643	.041	5.459	.643	.343	7.343
ATMOS SULFUR OXIDES	POUND	.331	.018	.069	.008	.174	4.951	3.662	.182	9.396
ATMOS CARBON MONOXIDE	POUND	.066	.007	.038	.078	.019	.783	.371	1.120	2.441
ATMOS ALDEHYDES	POUND	.001	.000	.001	.001	.000	.014	.006	.018	.041
ATMOS OTHER ORGANICS	POUND	.002	.000	.001	.003	.000	.027	.534	.041	.508
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	.000	.000	0.000	.000	.001	.001	.001	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.000	0.000	.000	.000	.000	.002	.002
ATMOS MERCURY	POUND	.000	.000	.000	0.000	.000	.000	.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.042	.004	.013	.119	.008	1.106	.362	.214	1.868
WATERBORNE BOD	POUND	.000	.000	.000	0.000	.000	.001	1.353	.001	1.355
WATERBORNE PHENOL	POUND	.000	.000	.000	0.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	0.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.000	.000	.000	0.000	.000	.000	.000	.000	.001
WATERBORNE COD	POUND	.000	.000	.000	0.000	.000	.002	.002	.002	.006
WATERBORNE SUSP SOLIDS	POUND	.333	.000	.000	0.000	.000	.071	.428	.001	1.034
WATERBORNE ACID	POUND	.015	.000	.003	0.000	.008	.200	.028	.000	.256
WATERBORNE METAL ION	POUND	.004	.000	.001	0.000	.002	.050	.007	.000	.064
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000	.050	0.000	.050
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
NAME	UNITS									
RAW MATERIALS	POUNDS	0.000	0.000	0.000	0.000	186.000	1245.000	50.422	0.000	1481.422
ENERGY	MIL BTU	.282	.012	.048	.680	.091	6.728	1.063	.431	9.336
WATER	THOU GAL	.604	.012	.170	.141	.007	.372	.021	.025	1.356
INDUSTRIAL SOLID WASTES	CUBIC FT	.019	.001	2.332	.175	.126	.369	.135	.001	3.173
ATM EMMISSIONS	POUNDS	.898	1.753	.794	2.184	1.124	17.472	8.864	2.706	35.800
WATERBORNE WASTES	POUNDS	.395	.005	.017	.119	.014	1.431	2.430	.220	4.636
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MIL BTU	.035	.008	.027	0.000	.004	.575	.303	.431	1.393
ENERGY SOURCE NAT GAS	MIL BTU	.166	.002	.007	.680	.037	5.354	.191	0.000	6.436
ENERGY SOURCE COAL	MIL BTU	.076	.002	.011	0.000	.050	.652	.183	0.000	.973
ENERGY SOURCE NUCL HYPWR	MIL BTU	.006	.000	.002	0.000	.001	.147	0.000	0.000	.156
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	.375	0.000	.375
INDEX OF ENVIRONMENTAL IMPACTS										
NAME	STANDARD VALUES									
RAW MATERIALS	1481.622	0.0	0.0	0.0	0.0	12.6	84.0	3.4	0.0	100.0
ENERGY	9.336	3.0	.1	.5	7.3	1.0	72.1	11.4	4.6	100.0
WATER	1.354	44.6	.9	12.6	10.4	.5	27.5	1.5	1.9	100.0
INDUSTRIAL SOLID WASTES	3.173	.6	.0	73.5	5.5	4.0	11.6	4.3	.0	100.0
ATM EMMISSIONS	35.800	2.5	4.9	2.2	6.1	3.1	48.8	24.8	7.6	100.0
WATERBORNE WASTES	4.636	8.5	.1	.4	2.6	.4	30.9	52.4	4.7	100.0
POST-CONSUMER SOL WASTE	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENERGY SOURCE PETROLEUM	1.393	2.5	.6	2.0	0.0	.3	41.5	21.9	31.2	100.0
ENERGY SOURCE NAT GAS	6.436	2.6	.0	.1	10.6	.6	83.2	3.0	0.0	100.0
ENERGY SOURCE COAL	.973	7.8	.2	1.1	0.0	5.1	67.0	18.8	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.156	3.5	.2	1.6	0.0	.4	94.3	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.375	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	100.0

Source: Midwest Research Institute.

TABLE 11

SUMMARY OF IMPACTS FOR 1,000 GALLONS OF MILK DELIVERED IN THE REFILLABLE GLASS 20-TRIP GALLON CONTAINER SYSTEM

		GLASS CONT MFG SYS 160	GLS GAL CONT MFG SYS TRAN 20-TP	GLASS CONT SYS WASH AND FILL	GLASS CONT SYS MILK DEL IVERY	GLASS GAL PCSW 20-TP	TRAN FILL SYS	TOTAL
INPUTS TO SYSTEMS								
NAME	UNITS							
MATERIAL WOOD FIBER	POUNDS	7.360	0.000	2.687	0.000	0.000	0.000	10.047
MATERIAL LIMESTONE	POUND	71.840	0.000	.811	0.000	0.000	0.000	72.651
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	1.976	0.000	0.000	0.000	1.976
MATERIAL GLASS SAND	POUND	106.560	0.000	0.000	0.000	0.000	0.000	106.560
MATERIAL NAT SODA ASH	POUND	34.560	0.000	0.000	0.000	0.000	0.000	34.560
MATERIAL FELDSPAR	POUND	12.000	0.000	0.000	0.000	0.000	0.000	12.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.152	.069	.061	.948	.013	.007	1.250
ENERGY SOURCE NAT GAS	MILL BTU	1.030	0.000	.226	0.000	0.000	0.000	1.256
ENERGY SOURCE COAL	MILL BTU	.156	0.000	.090	0.000	0.000	0.000	.246
ENERGY SOURCE MISC	MILL BTU	.025	0.000	.017	0.000	0.000	0.000	.042
ENERGY SOURCE WOOD FIBER	MILL BTU	.062	0.000	.048	0.000	0.000	0.000	.110
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	4.739	0.000	.438	0.000	0.000	0.000	5.178
ENERGY PROCESS	MIL BTU	1.419	0.000	.440	0.000	0.000	0.000	1.859
ENERGY TRANSPORT	MIL BTU	.005	.069	.001	.948	.013	.007	1.043
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	.000	0.000	0.000	0.000	.000
WATER VOLUME	THOU GAL	.213	.004	.364	.057	.001	.000	.639
OUTPUTS FROM SYSTEMS								
NAME	UNITS							
SOLID WASTES PROCESS	POUND	4.142	0.000	4.482	0.000	0.000	0.000	8.623
SOLID WASTES FUEL COMB	POUND	1.180	.016	.673	.230	.003	.002	2.103
SOLID WASTES MINING	POUND	32.274	0.000	1.205	0.000	0.000	0.000	33.479
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	5.020	0.000	5.020
ATMOS PARTICULATES	POUND	1.421	.009	.132	.101	.001	.001	1.665
ATMOS NITROGEN OXIDES	POUND	.968	.151	.291	1.498	.014	.015	2.936
ATMOS HYDROCARBONS	POUND	1.120	.055	.258	.861	.014	.005	2.313
ATMOS SULFUR OXIDES	POUND	1.474	.029	.462	.282	.003	.003	2.253
ATMOS CARBON MONOXIDE	POUND	.218	.179	.057	4.935	.094	.020	5.503
ATMOS ALDEHYDES	POUND	.004	.003	.001	.060	.001	.000	.069
ATMOS OTHER ORGANICS	POUND	.091	.006	.002	.197	.004	.001	.301
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	.002	0.000	0.000	0.000	.002
ATMOS AMMONIA	POUND	.000	.000	.000	.003	.000	.000	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.000	.013	.000	.000	.014
ATMOS MERCURY	POUND	.000	0.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	.014	0.000	0.000	0.000	.014
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.265	.034	.084	.490	.007	.003	.883
WATERBORNE BOD	POUND	.217	.000	.252	.001	.000	.000	.470
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.001	.000	.000	.001
WATERBORNE OIL	POUND	.000	.000	.000	.001	.000	.000	.001
WATERBORNE COD	POUND	.001	.000	.000	.005	.000	.000	.006
WATERBORNE SUSP SOLIDS	POUND	.165	.000	.390	.003	.000	.000	.558
WATERBORNE ACID	POUND	.041	.000	.026	.001	.000	.000	.068
WATERBORNE METAL ION	POUND	.010	.000	.006	.000	.000	.000	.017
WATERBORNE CHEMICALS	POUND	.008	0.000	0.000	0.000	0.000	0.000	.008
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	2.000	0.000	0.000	0.000	2.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	0.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS								
NAME	UNITS							
RAW MATERIALS	POUNDS	237.060	0.000	5.913	0.000	0.000	0.000	242.972
ENERGY	MIL BTU	1.425	.069	.442	.948	.013	.007	2.903
WATER	THOU GAL	.213	.004	.364	.057	.001	.000	.639
INDUSTRIAL SOLID WASTES	CUBIC FT	.500	.000	.086	.003	.000	.000	.597
ATM EMMISSIONS	POUNDS	5.295	.433	1.219	7.950	.132	.045	15.073
WATERBORNE WASTES	POUNDS	.706	.035	2.758	.502	.007	.004	4.013
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	5.020	0.000	5.020
ENERGY SOURCE PETROLEUM	MIL BTU	.152	.069	.061	.948	.013	.007	1.250
ENERGY SOURCE NAT GAS	MIL BTU	1.030	0.000	.226	0.000	0.000	0.000	1.256
ENERGY SOURCE COAL	MIL BTU	.156	0.000	.090	0.000	0.000	0.000	.246
ENERGY SOURCE NUCL HYPWR	MIL BTU	.025	0.000	.017	0.000	0.000	0.000	.042
ENERGY SOURCE WOOD WASTE	MIL BTU	.062	0.000	.048	0.000	0.000	0.000	.110
INDEX OF ENVIRONMENTAL IMPACTS								
NAME	STANDARD VALUES							
RAW MATERIALS	242.972	97.6	0.0	2.4	0.0	0.0	0.0	100.0
ENERGY	2.903	49.1	2.4	15.2	32.6	.4	.2	100.0
WATER	.639	33.3	.6	57.0	8.9	.1	.1	100.0
INDUSTRIAL SOLID WASTES	.597	85.0	.0	14.4	.5	.0	.0	100.0
ATM EMMISSIONS	15.073	35.1	2.9	8.1	52.7	.9	.3	100.0
WATERBORNE WASTES	4.013	17.6	.9	68.7	12.5	.2	.1	100.0
POST-CONSUMER SOL WASTE	5.020	0.0	0.0	0.0	0.0	100.0	0.0	100.0
ENERGY SOURCE PETROLEUM	1.250	12.2	5.5	4.9	75.8	1.0	.6	100.0
ENERGY SOURCE NAT GAS	1.256	82.0	0.0	18.0	0.0	0.0	0.0	100.0
ENERGY SOURCE COAL	.246	63.4	0.0	36.6	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.042	60.2	0.0	39.8	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.110	56.1	0.0	43.9	0.0	0.0	0.0	100.0

TABLE 12

SUMMARY OF IMPACTS FOR 1,000 GALLONS OF MILK DELIVERED IN THE REFILLABLE GLASS 20-TRIP HALF GALLON CONTAINER SYSTEM

		GLASS CONT MFG SYS 203 LB	GLS HGAL CONT MFG SYS TRAN 20-TP	GLASS CONT SYS WASH AND FILL	GLASS CONT SYS MILK DELIVERY	GLASS HGL PCSW 20-TP	TRAN FILL SYS	TOTAL
INPUTS TO SYSTEMS								
NAME	UNITS							
MATERIAL WOOD FIBER	POUNDS	9.338	0.000	5.353	0.000	0.000	0.000	14.691
MATERIAL LIMESTONE	POUND	91.147	0.030	1.616	0.000	0.000	0.000	92.763
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	2.577	0.000	0.000	0.000	2.577
MATERIAL GLASS SAND	POUND	135.198	0.000	0.000	0.000	0.000	0.000	135.198
MATERIAL NAT SODA ASH	POUND	43.848	0.000	0.000	0.000	0.000	0.000	43.848
MATERIAL FELDSPAR	POUND	15.225	0.000	0.000	0.000	0.000	0.000	15.225
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.193	.088	.129	1.033	.014	.007	1.464
ENERGY SOURCE NAT GAS	MILL BTU	1.307	0.000	.293	0.000	0.000	0.000	1.599
ENERGY SOURCE COAL	MILL BTU	.198	0.000	.198	0.000	0.000	0.000	.395
ENERGY SOURCE MISC	MILL BTU	.032	0.000	.037	0.000	0.000	0.000	.069
ENERGY SOURCE WOOD FIBER	MILL BTU	.078	0.000	.096	0.000	0.000	0.000	.175
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	6.013	0.000	.833	0.000	0.000	0.000	6.846
ENERGY PROCESS	MIL BTU	1.801	0.000	.750	0.000	0.000	0.000	2.551
ENERGY TRANSPORT	MIL BTU	.007	.088	.003	1.033	.014	.007	1.152
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	.000	0.000	0.000	0.000	.000
WATER VOLUME	THOU GAL	.270	.005	.423	.062	.001	.000	.761
OUTPUTS FROM SYSTEMS								
NAME	UNITS							
SOLID WASTES PROCESS	POUND	5.255	0.000	5.374	0.000	0.000	0.000	10.629
SOLID WASTES FUEL COMB	POUND	1.497	.020	1.450	.250	.004	.002	3.222
SOLID WASTES MINING	POUND	40.947	0.000	2.676	0.000	0.000	0.000	43.623
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	5.440	0.000	5.440
ATMOS PARTICULATES	POUND	1.803	.011	.282	.110	.002	.001	2.208
ATMOS NITROGEN OXIDES	POUND	1.228	.192	.533	1.633	.015	.015	3.615
ATMOS HYDROCARBONS	POUND	1.421	.070	.374	.938	.016	.005	2.824
ATMOS SULFUR OXIDES	POUND	1.870	.037	1.020	.308	.004	.003	3.242
ATMOS CARBON MONOXIDE	POUND	.276	.227	.100	5.380	.104	.020	6.107
ATMOS ALDEHYDES	POUND	.005	.004	.001	.065	.001	.000	.076
ATMOS OTHER ORGANICS	POUND	.115	.008	.003	.215	.004	.001	.346
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	.004	0.000	0.000	0.000	.004
ATMOS AMMONIA	POUND	.000	.000	.000	.003	.000	.000	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.000	.014	.000	.000	.015
ATMOS MERCURY	POUND	.000	0.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	.017	0.000	0.000	0.000	.017
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.336	.043	.122	.534	.008	.003	1.047
WATERBORNE BOD	POUND	.275	.000	.275	.001	.000	.000	.551
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.001	.000	.000	.001
WATERBORNE OIL	POUND	.000	.000	.000	.001	.000	.000	.001
WATERBORNE COD	POUND	.001	.000	.000	.006	.000	.000	.007
WATERBORNE SUSP SOLIDS	POUND	.210	.000	.429	.003	.000	.000	.643
WATERBORNE ACID	POUND	.052	.000	.058	.001	.000	.000	.110
WATERBORNE METAL ION	POUND	.013	.000	.014	.000	.000	.000	.027
WATERBORNE CHEMICALS	POUND	.010	0.000	0.000	0.000	0.000	0.000	.010
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	2.000	0.000	0.000	0.000	2.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	0.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS								
NAME	UNITS							
RAW MATERIALS	POUNDS	300.769	0.000	10.379	0.000	0.000	0.000	311.148
ENERGY	MIL BTU	1.888	.088	.753	1.033	.014	.007	3.703
WATER	THOU GAL	.270	.005	.423	.062	.001	.000	.761
INDUSTRIAL SOLID WASTES	CUBIC FT	.644	.000	.128	.003	.000	.000	.776
ATM EMMISSIONS	POUNDS	6.718	.549	2.334	8.666	.147	.045	18.458
WATERBORNE WASTES	POUNDS	.896	.045	2.897	.548	.008	.004	4.397
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	5.440	0.000	5.440
ENERGY SOURCE PETROLEUM	MIL BTU	.193	.088	.129	1.033	.014	.007	1.464
ENERGY SOURCE NAT GAS	MIL BTU	1.307	0.000	.293	0.000	0.000	0.000	1.599
ENERGY SOURCE COAL	MIL BTU	.198	0.000	.198	0.000	0.000	0.000	.395
ENERGY SOURCE NUCL HYPWR	MIL BTU	.032	0.000	.037	0.000	0.000	0.000	.069
ENERGY SOURCE WOOD WASTE	MIL BTU	.078	0.000	.096	0.000	0.000	0.000	.175
INDEX OF ENVIRONMENTAL IMPACTS								
NAME	STANDARD VALUES							
RAW MATERIALS	311.148	96.7	0.0	3.3	0.0	0.0	0.0	100.0
ENERGY	3.703	48.8	2.4	20.3	27.9	.4	.2	100.0
WATER	.761	35.4	.7	55.6	8.2	.1	.1	100.0
INDUSTRIAL SOLID WASTES	.776	83.0	.0	16.5	.4	.0	.0	100.0
ATM EMMISSIONS	18.458	36.4	3.0	12.6	46.9	.8	.2	100.0
WATERBORNE WASTES	4.397	20.4	1.0	65.9	12.5	.2	.1	100.0
POST-CONSUMER SOL WASTE	5.440	0.0	0.0	0.0	0.0	100.0	0.0	100.0
ENERGY SOURCE PETROLEUM	1.464	13.2	6.0	8.8	70.5	1.0	.5	100.0
ENERGY SOURCE NAT GAS	1.599	81.7	0.0	18.3	0.0	0.0	0.0	100.0
ENERGY SOURCE COAL	.395	50.0	0.0	50.0	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.069	46.1	0.0	53.9	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.175	44.9	0.0	55.1	0.0	0.0	0.0	100.0

TABLE 13

SUMMARY OF IMPACTS FOR 1,000 GALLONS OF MILK DELIVERED IN THE REFILLABLE GLASS 20-TRIP HALF PINT CONTAINER SYSTEM

		GLASS CONT MFG SYS 400 LB	GLA HPT CONT MFG SYS TRAN 20-TP	GLASS CONT SYS WASH AND FILL	GLASS CONT SYS MILK DEL IVERY	GLASS HPT PCSW 20-TP	TRAN FILL SYS	TOTAL
INPUTS TO SYSTEMS								
NAME	UNITS							
MATERIAL WOOD FIBER	POUNDS	18.401	0.000	42.983	0.000	0.000	0.000	61.384
MATERIAL LIMESTONE	POUND	179.600	0.000	12.976	0.000	0.000	0.000	192.576
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	11.062	0.000	0.000	0.000	11.062
MATERIAL GLASS SAND	POUND	266.400	0.000	0.000	0.000	0.000	0.000	266.400
MATERIAL NAT SODA ASH	POUND	86.400	0.000	0.000	0.000	0.000	0.000	86.400
MATERIAL FELDSPAR	POUND	30.000	0.000	0.000	0.000	0.000	0.000	30.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.381	.173	.854	.964	.019	.086	2.477
ENERGY SOURCE NAT GAS	MILL BTU	2.575	0.000	.839	0.000	0.000	0.000	3.414
ENERGY SOURCE COAL	MILL BTU	.389	0.000	1.142	0.000	0.000	0.000	1.532
ENERGY SOURCE MISC	MILL BTU	.063	0.000	.198	0.000	0.000	0.000	.260
ENERGY SOURCE WOOD FIBER	MILL BTU	.155	0.000	.773	0.000	0.000	0.000	.927
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	11.848	0.000	6.397	0.000	0.000	0.000	18.245
ENERGY PROCESS	MIL BTU	3.548	0.000	3.783	0.000	0.000	0.000	7.331
ENERGY TRANSPORT	MIL BTU	.013	.173	.024	.964	.019	.086	1.279
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	.003	0.000	0.000	0.000	.003
WATER VOLUME	THOU GAL	.532	.010	1.230	.057	.001	.005	1.835
OUTPUTS FROM SYSTEMS								
NAME	UNITS							
SOLID WASTES PROCESS	POUND	10.354	0.000	17.970	0.000	0.000	0.000	28.324
SOLID WASTES FUEL COMB	POUND	2.949	.040	9.035	.230	.005	.020	12.279
SOLID WASTES MINING	POUND	80.685	0.000	14.225	0.000	0.000	0.000	94.909
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	6.940	0.000	6.940
ATMOS PARTICULATES	POUND	3.552	.023	1.679	.103	.002	.010	5.368
ATMOS NITROGEN OXIDES	POUND	2.419	.378	2.620	1.776	.020	.186	7.398
ATMOS HYDROCARBONS	POUND	2.800	.137	1.372	.789	.020	.067	5.185
ATMOS SULFUR OXIDES	POUND	3.605	.073	5.760	.306	.005	.032	9.441
ATMOS CARBON MONOXIDE	POUND	.544	.448	.529	4.055	.135	.259	5.972
ATMOS ALDEHYDES	POUND	.009	.007	.006	.050	.002	.004	.077
ATMOS OTHER ORGANICS	POUND	.227	.016	.012	.152	.006	.009	.423
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	.032	0.000	0.000	0.000	.032
ATMOS AMMONIA	POUND	.001	.000	.000	.003	.000	.000	.004
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.001	.000	.010	.000	.001	.012
ATMOS MERCURY	POUND	.000	0.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	.059	0.000	0.000	0.000	.059
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.661	.086	.572	.491	.010	.043	1.863
WATERBORNE BOD	POUND	.542	.000	.588	.001	.000	.000	1.131
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.001	.000	.000	.001
WATERBORNE OIL	POUND	.000	.000	.000	.001	.000	.000	.001
WATERBORNE COD	POUND	.002	.001	.001	.005	.000	.000	.009
WATERBORNE SUSP SOLIDS	POUND	.413	.001	.985	.003	.000	.000	1.402
WATERBORNE ACID	POUND	.102	.000	.326	.001	.000	.000	.429
WATERBORNE METAL ION	POUND	.026	.000	.077	.000	.000	.000	.103
WATERBORNE CHEMICALS	POUND	.020	0.000	0.000	0.000	0.000	0.000	.020
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	2.000	0.000	0.000	0.000	2.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	0.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS								
NAME	UNITS							
RAW MATERIALS	POUNDS	592.649	0.000	73.418	0.000	0.000	0.000	666.067
ENERGY	MIL BTU	3.562	.173	3.809	.964	.019	.086	8.613
WATER	THOU GAL	.532	.010	1.230	.057	.001	.005	1.835
INDUSTRIAL SOLID WASTES	CUBIC FT	1.269	.001	.557	.003	.000	.000	1.829
ATM EMMISSIONS	POUNDS	13.237	1.082	12.050	7.243	.191	.566	34.369
WATERBORNE WASTES	POUNDS	1.766	.088	4.544	.503	.010	.044	6.960
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	6.940	0.000	6.940
ENERGY SOURCE PETROLEUM	MIL BTU	.381	.173	.854	.964	.019	.086	2.477
ENERGY SOURCE NAT GAS	MIL BTU	2.575	0.000	.839	0.000	0.000	0.000	3.414
ENERGY SOURCE COAL	MIL BTU	.389	0.000	1.142	0.000	0.000	0.000	1.532
ENERGY SOURCE NUCL HYPWR	MIL BTU	.063	0.000	.198	0.000	0.000	0.000	.260
ENERGY SOURCE WOOD WASTE	MIL BTU	.155	0.000	.773	0.000	0.000	0.000	.927
INDEX OF ENVIRONMENTAL IMPACTS								
NAME	STANDARD VALUES							
RAW MATERIALS	666.067	89.0	0.0	11.0	0.0	0.0	0.0	100.0
ENERGY	8.613	41.4	2.0	44.2	11.2	.2	1.0	100.0
WATER	1.835	29.0	.5	67.0	3.1	.1	.3	100.0
INDUSTRIAL SOLID WASTES	1.829	69.4	.0	30.4	.2	.0	.0	100.0
ATM EMMISSIONS	34.369	38.5	3.1	35.1	21.1	.6	1.6	100.0
WATERBORNE WASTES	6.960	25.4	1.3	65.4	7.2	.1	.6	100.0
POST-CONSUMER SOL WASTE	6.940	0.0	0.0	0.0	0.0	100.0	0.0	100.0
ENERGY SOURCE PETROLEUM	2.477	15.4	7.0	34.5	38.9	.8	3.5	100.0
ENERGY SOURCE NAT GAS	3.414	75.4	0.0	24.6	0.0	0.0	0.0	100.0
ENERGY SOURCE COAL	1.532	25.4	0.0	74.6	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.260	24.0	0.0	76.0	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.927	16.7	0.0	83.3	0.0	0.0	0.0	100.0

TABLE 14

PROCESSES WITH HIGHEST IMPACTS BY IMPACT CATEGORY FOR MILK DELIVERED IN 20-TRIP GLASS ONE GALLON JUGS

Impact category	Process with numerically highest impact
Raw materials	Bottle manufacture
Energy	Bottle manufacture
Water	Fill and wash - bottle manufacture
Industrial solid wastes	Bottle manufacture
Atmospheric emissions	Milk distribution
Waterborne wastes	Fill and wash
Postconsumer solid wastes	Waste disposal

Source: Franklin Associates, Ltd., for Midwest Research Institute.

4. Bottle trip rate effect: The effects of the number of trips on the impact profile are summarized in Table 15 and Figure 13. All impacts decline with increasing trips, but the rate of decline decreases as the trip rates rise. For example, the energy requirement is reduced by 40 percent of the 5-trip bottle value between 5 and 10 trips; by 60 percent of the 5-trip value by going to 20 trips; and by 73 percent of the 5-trip value by achieving 50 trips.

All of the impacts decline by differing amounts, as shown by Figure 13, but all impacts are reduced substantially by reuse of the glass container. This occurs because the steps required for reusing bottles (washing, transporting, etc.) have lower aggregate impacts than manufacturing a new bottle for each filling of milk.

5. Size effect: At present, consumers have a choice of container sizes in which to purchase milk, with most milk in the household market being sold in one gallon or half gallon sizes. There is also considerable milk sold in institutional markets, where the half pint size dominates. The impacts resulting from the same quantity of milk delivered in the various sizes of containers are summarized in Table 16. One gallon containers require far fewer resources and have a much lower impact on the environment than half gallon containers, and the half gallon is more favorably positioned than the half pint in every category. This occurs because the larger jugs require less glass per unit volume than do smaller sizes, and because washing, transporting and packaging are more efficient for the larger sizes.

TABLE 15

SUMMARY OF IMPACTS FOR 1,000 GALLONS OF MILK DELIVERIES IN THE REFILLABLE GLASS GALLON - 5, 10, 20, 50, 75, and 100 TRIP CONTAINERS

		5 TRIP	10 TRIP	20 TRIP	50 TRIP	75 TRIP	100 TRIP
INPUTS TO SYSTEMS NAME	UNITS						
MATERIAL WOOD FIBER	POUNDS	32.120	17.408	10.047	5.631	4.619	4.159
MATERIAL LIMESTONE	POUND	288.171	144.491	72.651	29.547	19.669	15.179
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	1.976	1.976	1.976	1.976	1.976	1.976
MATERIAL GLASS SAND	POUND	426.240	213.120	106.560	42.624	27.972	21.312
MATERIAL NAT SODA ASH	POUND	138.240	69.120	34.560	13.824	9.072	6.912
MATERIAL FELDSPAR	POUND	48.000	24.000	12.000	4.800	3.150	2.400
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	1.955	1.484	1.250	1.110	1.078	1.063
ENERGY SOURCE NAT GAS	MILL BTU	4.345	2.286	1.256	.638	.496	.432
ENERGY SOURCE COAL	MILL BTU	.713	.401	.246	.152	.131	.121
ENERGY SOURCE MISC	MILL BTU	.117	.067	.042	.027	.023	.022
ENERGY SOURCE WOOD FIBER	MILL BTU	.296	.172	.110	.073	.065	.061
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	19.395	9.917	5.178	2.334	1.682	1.386
ENERGY PROCESS	MIL BTU	6.118	3.279	1.859	1.008	.813	.724
ENERGY TRANSPORT	MIL BTU	1.307	1.131	1.043	.992	.980	.974
ENERGY OF MATL RESOURCE	MIL BTU	.000	.000	.000	.000	.000	.000
WATER VOLUME	THOU GAL	1.292	.857	.639	.509	.479	.465
OUTPUTS FROM SYSTEMS NAME	UNITS						
SOLID WASTES PROCESS	POUND	21.048	12.765	8.623	6.138	5.569	5.310
SOLID WASTES FUEL COMB	POUND	5.700	3.302	2.103	1.384	1.219	1.144
SOLID WASTES MINING	POUND	130.300	65.753	33.479	14.115	9.677	7.660
SOLID WASTE POST-CONSUM	CUBIC FT	19.920	10.020	5.020	2.100	1.440	1.110
ATMOS PARTICULATES	POUND	5.959	3.096	1.665	.806	.610	.520
ATMOS NITROGEN OXIDES	POUND	6.336	4.069	2.936	2.257	2.102	2.031
ATMOS HYDROCARBONS	POUND	5.882	3.502	2.313	1.600	1.437	1.362
ATMOS SULFUR OXIDES	POUND	6.773	3.760	2.253	1.350	1.143	1.048
ATMOS CARBON MONOXIDE	POUND	6.986	5.994	5.503	5.213	5.148	5.113
ATMOS ALDEHYDES	POUND	.092	.076	.069	.064	.063	.063
ATMOS OTHER ORGANICS	POUND	.605	.402	.301	.240	.226	.220
ATMOS ODOROUS SULFUR	POUND	.002	.002	.002	.002	.002	.002
ATMOS AMMONIA	POUND	.004	.004	.003	.003	.003	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.015	.014	.014	.013	.013	.013
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	.014	.014	.014	.014	.014	.014
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	1.801	1.189	.883	.700	.658	.638
WATERBORNE BOD	POUND	1.121	.687	.470	.340	.311	.297
WATERBORNE PHENOL	POUND	.001	.001	.001	.000	.000	.000
WATERBORNE SULFIDES	POUND	.001	.001	.001	.001	.001	.001
WATERBORNE OIL	POUND	.001	.001	.001	.001	.001	.001
WATERBORNE COD	POUND	.010	.007	.006	.006	.005	.005
WATERBORNE SUSP SOLIDS	POUND	1.055	.724	.558	.459	.436	.424
WATERBORNE ACID	POUND	.191	.109	.068	.043	.038	.035
WATERBORNE METAL ION	POUND	.047	.027	.017	.011	.009	.009
WATERBORNE CHEMICALS	POUND	.032	.016	.008	.003	.002	.002
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	2.000	2.000	2.000	2.000	2.000	2.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	.000	.000	.000	.000	.000	.000
WATERBORNE LEAD	POUND	.000	.000	.000	.000	.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS						
RAW MATERIALS	POUNDS	954.151	480.032	242.972	100.737	69.141	53.324
ENERGY	MIL BTU	7.425	4.410	2.903	2.000	1.793	1.544
WATER	THOU GAL	1.292	.857	.639	.519	.479	.465
INDUSTRIAL SOLID WASTES	CUBIC FT	2.120	1.135	.597	.292	.222	.191
ATM EMMISSIONS	POUNDS	32.668	20.933	15.073	11.563	10.761	10.348
WATERBORNE WASTES	POUNDS	6.259	4.761	4.013	3.564	3.461	3.414
POST-CONSUMER SOL WASTE	CUBIC FT	19.920	10.020	5.020	2.100	1.440	1.110
ENERGY SOURCE PETROLEUM	MIL BTU	1.955	1.484	1.250	1.110	1.078	1.063
ENERGY SOURCE NAT GAS	MIL BTU	4.345	2.286	1.256	.638	.496	.432
ENERGY SOURCE COAL	MIL BTU	.713	.401	.246	.152	.131	.121
ENERGY SOURCE NUCL HYDRO	MIL BTU	.117	.067	.042	.027	.023	.022
ENERGY SOURCE WOOD WASTE	MIL BTU	.296	.172	.110	.073	.065	.061

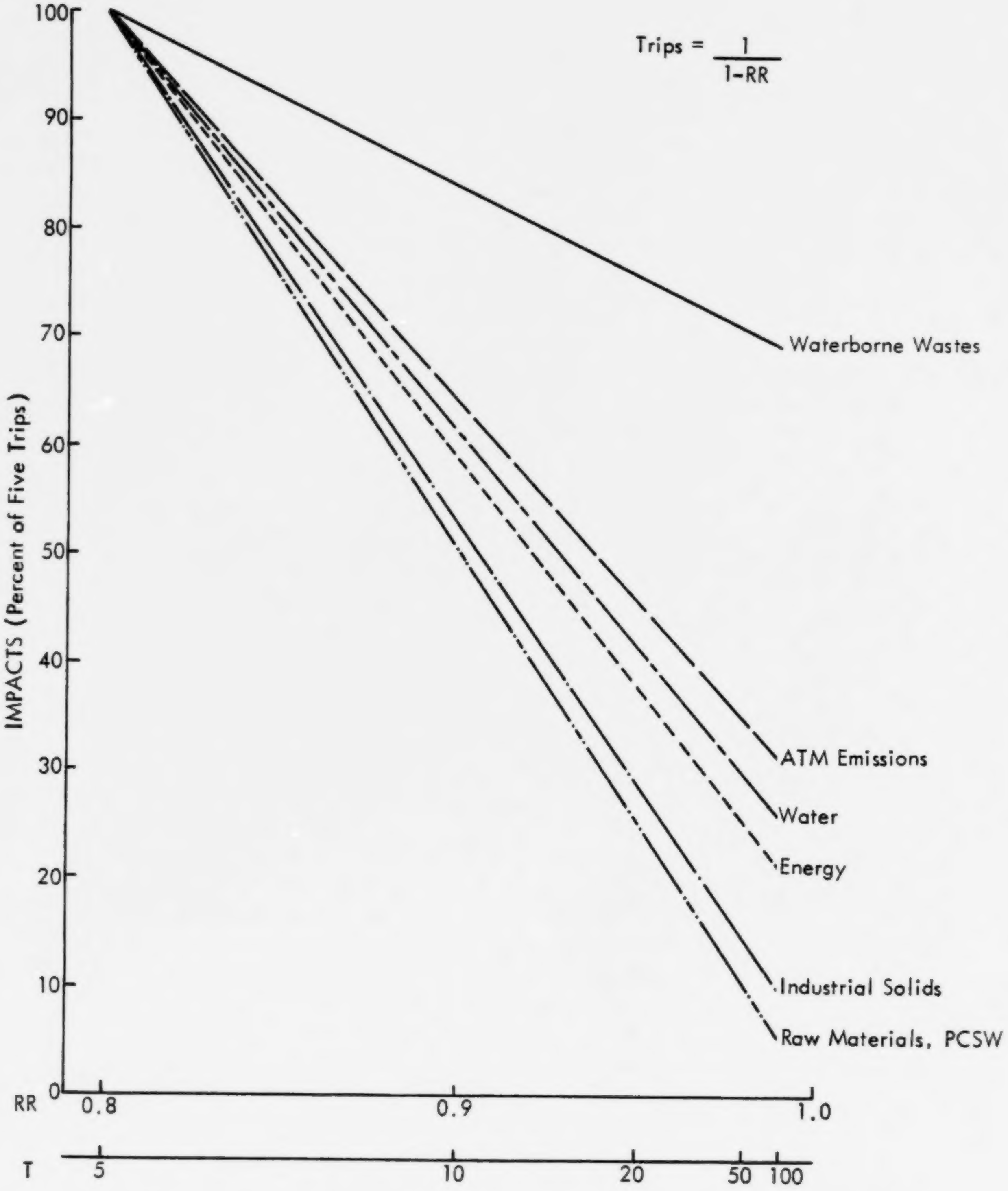


Figure 13. Graph shows the effects of the number of trips on the impact profile.

TABLE 16

SUMMARY OF IMPACTS FOR 1,000 GALLONS OF MILK DELIVERED IN EACH REFILLABLE GLASS 20-TRIP CONTAINER

Impact Category		20-Trip Glass Gallon	20-Trip Glass Half Gallon	20-Trip Glass Half Pint
Raw Materials	Pounds	242.972	311.148	666.067
Energy	Million Btu	2.903	3.703	8.613
Water	Thousand Gallons	0.639	0.761	1.835
Industrial Solid Wastes	Cubic Feet	0.597	0.776	1.829
Atmospheric Emissions	Pounds	15.073	18.458	34.369
Waterborne Wastes	Pounds	4.013	4.397	6.960
Postconsumer Solid Waste	Cubic Feet	5.020	5.440	6.940
Energy Source Petroleum	Million Btu	1.250	1.464	2.477
Energy Source Natural Gas	Million Btu	1.256	1.599	3.414
Energy Source Coal	Million Btu	0.246	0.395	1.532
Energy Source Nuclear Horsepower	Million Btu	0.042	0.069	0.260
Energy Source Wood Waste	Million Btu	0.110	0.175	0.927

C. Refillable Plastic Containers

1. Overview: Flow diagrams for the refillable plastic systems are shown in Figures 14, 15, and 16. Natural gas and crude oil are the raw materials for ethylene manufacture. The feedstocks for ethylene manufacture are currently 75 percent light gases and 25 percent heavier feeds. The ethylene is converted into high density polyethylene resin which is used in blow-molding the refillable container. The finished containers are packaged in corrugated containers and shipped to the dairies.

The refillable plastic bottle can generally be refilled over 50 times before it is taken out of service. However, useful life has been reported to achieve as many as 200 fillings. This report examines trip rates of 5, 10, 20, 50, 75, and 100.

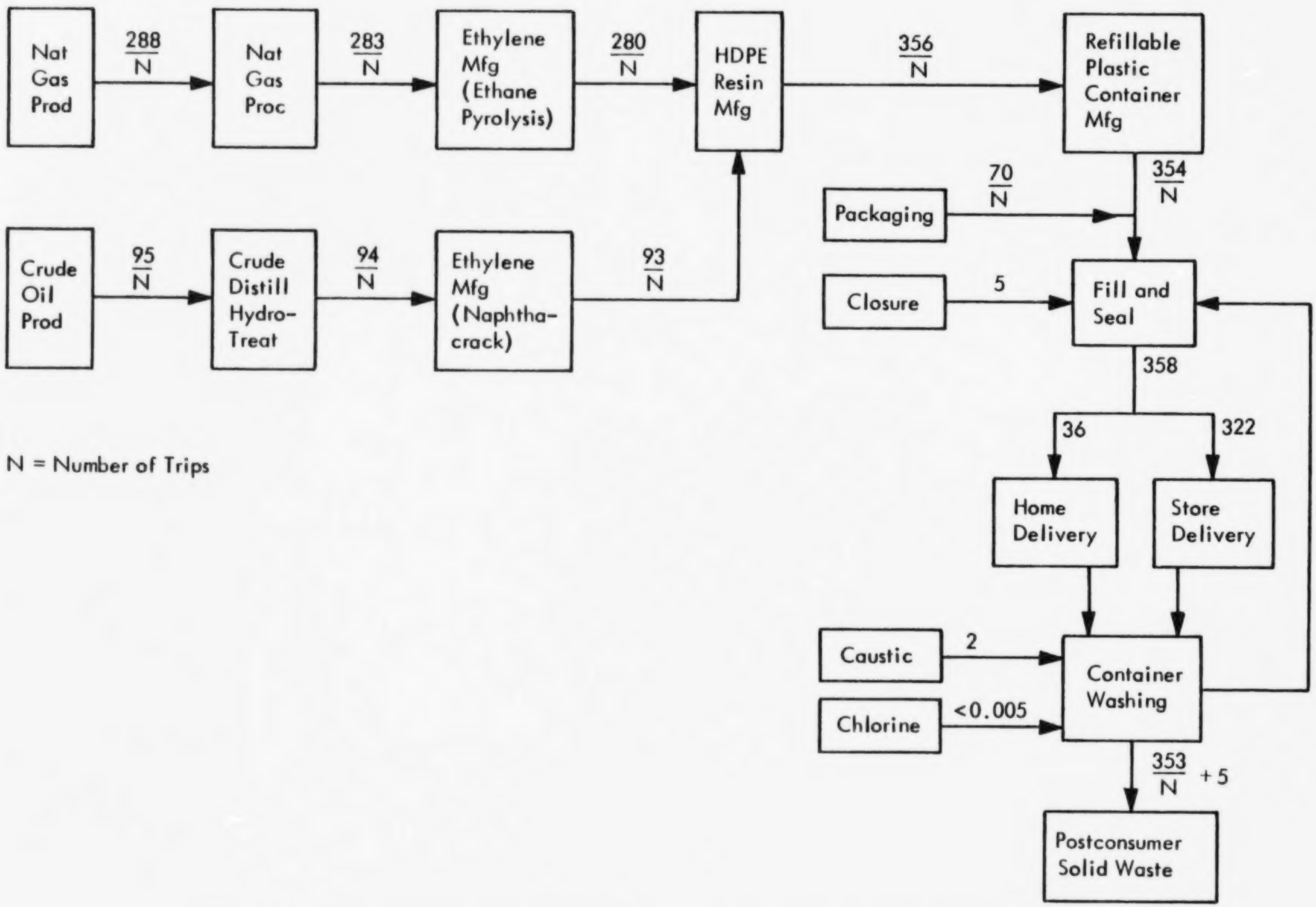

Nat Gas Prod
288/N
Nat Gas Proc
283/N
Ethylene Mfg (Ethane Pyrolysis)
280/N
HDPE Resin Mfg
356/N
Refillable Plastic Container Mfg
354/N
Crude Oil Prod
95/N
Crude Distill Hydro-Treat
94/N
Ethylene Mfg (Naphtha-crack)
93/N
Packaging
70/N
Closure
5
Fill and Seal
358
36
322
Home Delivery
Store Delivery
Caustic
2
Chlorine
<0.005
Container Washing
353/N +5
Postconsumer Solid Waste
N = Number of Trips

Figure 14. Flow diagram shows delivery of 1,000 gallons of milk in refillable plastic gallon containers (in pounds).

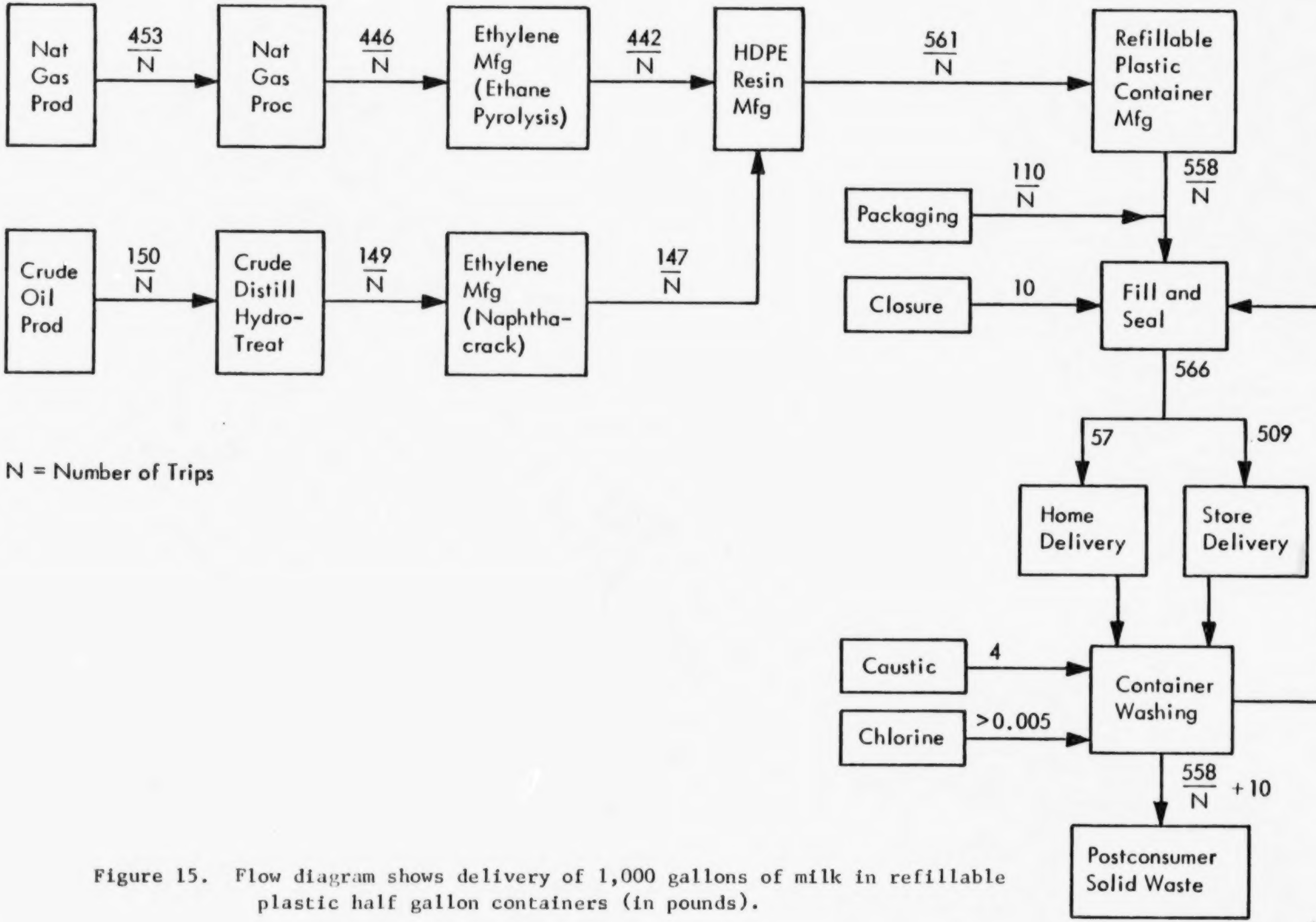

Nat Gas Prod
453/N
Nat Gas Proc
446/N
Ethylene Mfg (Ethane Pyrolysis)
442/N
HDPE Resin Mfg
561/N
Refillable Plastic Container Mfg
558/N
Crude Oil Prod
150/N
Crude Distill Hydro-Treat
149/N
Ethylene Mfg (Naphtha-crack)
147/N
Packaging
110/N
Closure
10
Fill and Seal
566
57
509
Home Delivery
Store Delivery
Caustic
4
Chlorine
>0.005
Container Washing
558/N +10
Postconsumer Solid Waste
N = Number of Trips

Figure 15. Flow diagram shows delivery of 1,000 gallons of milk in refillable plastic half gallon containers (in pounds).

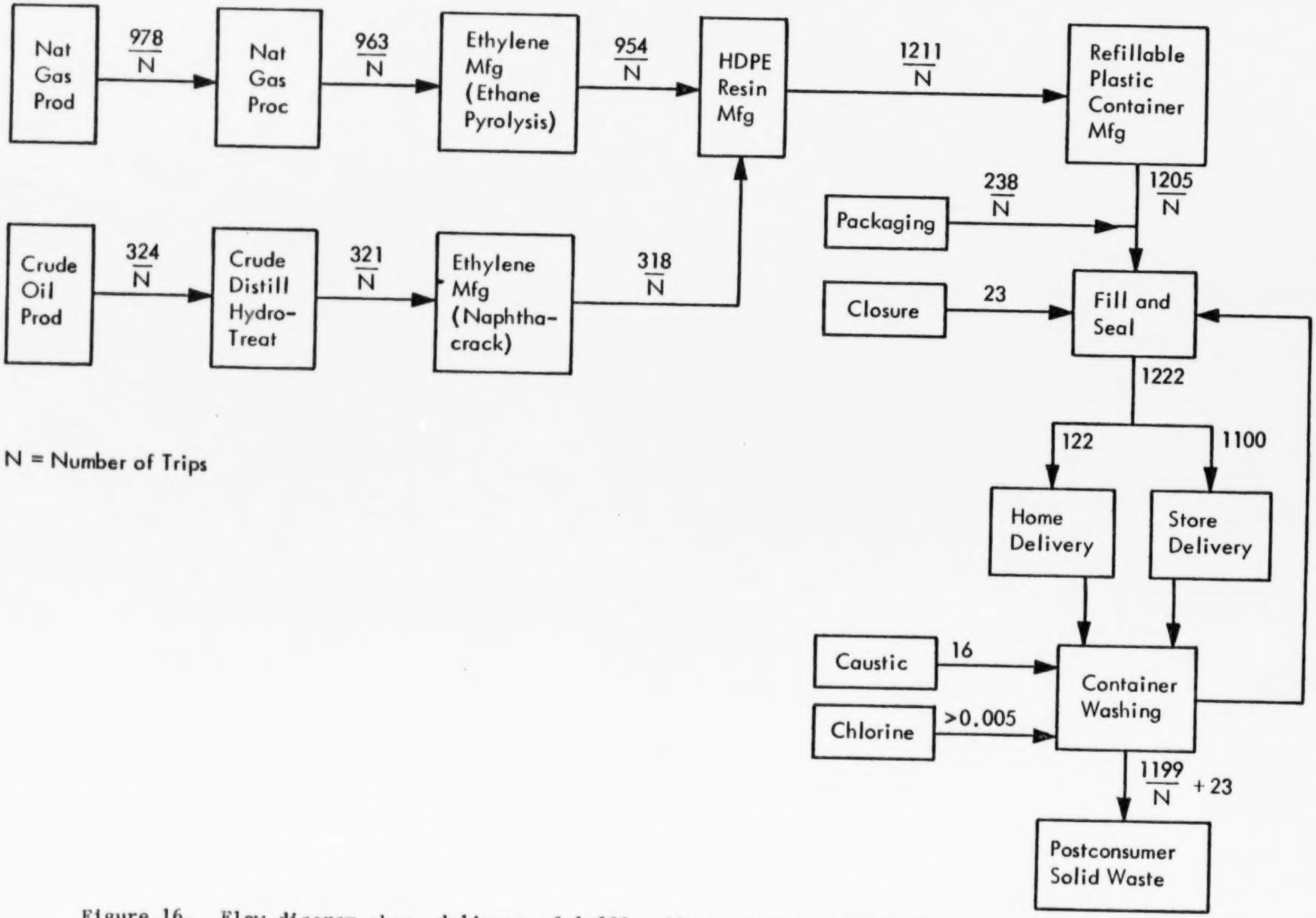

Nat Gas Prod
978/N
Nat Gas Proc
963/N
Ethylene Mfg (Ethane Pyrolysis)
954/N
HDPE Resin Mfg
1211/N
Refillable Plastic Container Mfg
Crude Oil Prod
324/N
Crude Distill Hydro-Treat
321/N
Ethylene Mfg (Naphtha-crack)
318/N
Packaging
238/N
1205/N
Closure
23
Fill and Seal
1222
122
1100
Home Delivery
Store Delivery
Caustic
16
Chlorine
>0.005
Container Washing
1199/N + 23
Postconsumer Solid Waste
N = Number of Trips

Figure 16. Flow diagram shows delivery of 1,000 gallons of milk in refillable plastic half pint containers (in pounds).

2. Profile analysis: The basic impact data for 1,000 gallons of the one gallon 50-trip plastic bottle system are given in Table 17. The system contains nine separate processes. The paper closure system requires the most raw materials (because 50 closures are used for 50 fillings and only one bottle is used). As may be noted, the energy use is concentrated in the milk delivery process. The delivery requires 0.74 million Btu, representing 47.3 percent of the total system energy. The next most energy-intensive processes are the HDPE resin system at 0.283 million Btu per 1,000 gallons of milk, and the closure system at 0.216 million Btu per 1,000 gallons of milk. The bottle washing process requires 0.199 million Btu per 1,000 gallons and represents 12.8 percent of the total system energy. The washing process shows the most waterborne wastes, accounting for 67.5 percent of the waterborne wastes for the entire refillable bottle system.

An important fact revealed by the study is that the impacts associated with delivering the milk to the store or o a residence represent a significant portion of the total impacts for a refillable container system.

In Table 18 below are listed the seven general impact categories along with the processes which show the greatest impact for each category for the 50-trip refillable bottle system.

TABLE 18

IMPACT ANALYSIS--50-TRIP REFILLABLE PLASTIC GALLON CONTAINER SYSTEM

Impact category	Processes with highest impacts	Percent of total by this process
Raw materials	Closure system	48.3
Energy	Milk delivery	47.4
Water	Bottle washing	68.7
Industrial solid waste	Bottle washing	46.8
Atmospheric emissions	Milk delivery	70.3
Waterborne wastes	Bottle washing	67.5
Postconsumer solid waste	Postconsumer solid waste	100.0

Source: Midwest Research Institute.

TABLE 17

IMPACTS ON 1,000 GALLONS OF THE 50-TRIP REFILLABLE GALLON PLASTIC BOTTLE

		HDPE RESIN SYS 7.12 LB	RET PLS GALLON MFG 7.09 LB	RET PLS GALLON PKG	PAPER CLOSURE SYS	RET PLS GALLON WASHING	RET PLS GALLON FILL CAP	TRAN GAL RET PLS 50 TP SY	RET PLS GALLON MILK TRAN	RET PLS GALLON PCS*	TOTAL
INPUTS TO SYSTEMS											
NAME	UNITS										
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	.978	2.650	0.000	0.000	0.000	0.000	0.000	3.628
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	.800	0.000	0.000	0.000	0.000	0.000	.800
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	.597	1.286	0.000	0.000	0.000	0.000	1.884
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.046	.010	.006	.052	.014	.003	.015	.738	.005	.889
ENERGY SOURCE NAT GAS	MILL BTU	.213	.025	.004	.036	.143	.003	.001	0.000	0.000	.425
ENERGY SOURCE COAL	MILL BTU	.020	.024	.004	.068	.034	.008	0.000	0.000	0.000	.158
ENERGY SOURCE MISC	MILL BTU	.005	.005	0.000	.012	.008	.002	0.000	0.000	0.000	.031
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.008	.048	0.000	0.000	0.000	0.000	0.000	.056
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	.399	0.000	.098	.392	1.997	0.000	0.000	0.000	0.000	2.886
ENERGY PROCESS	MIL BTU	.109	.064	.022	.214	.199	.016	0.000	0.000	0.000	.624
ENERGY TRANSPORT	MIL BTU	.004	0.000	.000	.001	.000	0.000	.015	.738	.005	.764
ENERGY OF MATL RESOURCE	MIL BTU	.171	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	.171
WATER VOLUME	THOU GAL	.013	.020	.000	.057	.300	.000	.001	.044	.000	.436
OUTPUTS FROM SYSTEMS											
NAME	UNITS										
SOLID WASTES PROCESS	POUND	.170	.035	.094	.887	3.110	.400	0.000	0.000	0.000	4.697
SOLID WASTES FUEL COMB	POUND	.118	.138	.064	.544	.200	.047	.003	.179	.001	1.294
SOLID WASTES MINING	POUND	.321	.376	.055	.839	.566	.128	0.000	0.000	0.000	2.285
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.003	2.003
ATMOS PARTICULATES	POUND	.028	.030	.055	.100	.046	.010	.002	.078	.001	.350
ATMOS NITROGEN OXIDES	POUND	.127	.059	.023	.149	.141	.017	.036	1.169	.006	1.727
ATMOS HYDROCARBONS	POUND	.354	.034	.014	.069	.151	.007	.013	.670	.006	1.317
ATMOS SULFUR OXIDES	POUND	.127	.129	.078	.341	.189	.044	.006	.220	.001	1.136
ATMOS CARBON MONOXIDE	POUND	.026	.008	.008	.030	.024	.002	.040	3.840	.053	4.032
ATMOS ALDEHYDES	POUND	.000	.000	.000	.000	.000	.000	.001	.047	.000	.049
ATMOS OTHER ORGANICS	POUND	.000	.000	.011	.001	.001	.000	.001	.153	.006	.173
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	.002	.000	0.000	0.000	0.000	0.000	.002
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	.000	0.000	.000	.002	.000	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	.000	.000	0.000	.000	.010	.000	.010
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	.003	.010	0.000	0.000	0.000	0.000	.013
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.038	.005	.008	.031	.042	.001	.007	.382	.003	.514
WATERBORNE BOD	POUND	.002	.000	.029	.022	.069	.160	.000	.001	.000	.282
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE OIL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE COD	POUND	.013	.000	.000	.000	.000	.000	.000	.004	.000	.017
WATERBORNE SUSP SOLIDS	POUND	.004	.000	.013	.039	.103	.240	.000	.002	.000	.402
WATERBORNE ACID	POUND	.006	.007	.001	.019	.010	.002	.000	.001	.000	.047
WATERBORNE METAL ION	POUND	.002	.002	.000	.005	.003	.001	.000	.000	.000	.011
WATERBORNE CHEMICALS	POUND	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	.001
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	1.960	0.000	0.000	0.000	0.000	1.960
WATERBORNE CHROMIUM	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS											
NAME	UNITS										
RAW MATERIALS	POUNDS	.399	0.000	1.077	4.439	3.283	0.000	0.000	0.000	0.000	9.198
ENERGY	MIL BTU	.283	.064	.023	.216	.199	.016	.015	.738	.005	1.559
WATER	THOU GAL	.013	.020	.000	.057	.300	.000	.001	.044	.000	.436
INDUSTRIAL SOLID WASTES	CUBIC FT	.008	.007	.003	.031	.052	.008	.000	.002	.000	.112
ATM EMMISSIONS	POUNDS	.663	.260	.189	.696	.562	.080	.099	6.190	.071	8.809
WATERBORNE WASTES	POUNDS	.065	.015	.052	.117	2.187	.404	.008	.391	.003	3.240
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.003	2.003
ENERGY SOURCE PETROLEUM	MIL BTU	.046	.010	.006	.052	.014	.003	.015	.738	.005	.889
ENERGY SOURCE NAT GAS	MIL BTU	.213	.025	.004	.036	.143	.003	.001	0.000	0.000	.425
ENERGY SOURCE COAL	MIL BTU	.020	.024	.004	.068	.034	.008	0.000	0.000	0.000	.158
ENERGY SOURCE NUCL HYPWR	MIL BTU	.005	.005	0.000	.012	.008	.002	0.000	0.000	0.000	.031
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.008	.048	0.000	0.000	0.000	0.000	0.000	.056
INDEX OF ENVIRONMENTAL IMPACTS											
NAME	STANDARD VALUES										
RAW MATERIALS	9.198	4.3	0.0	11.7	48.3	35.7	0.0	0.0	0.0	0.0	100.0
ENERGY	1.559	18.2	4.1	1.4	13.8	12.8	1.1	1.0	47.4	.3	100.0
WATER	.436	3.0	4.7	.1	13.0	68.7	.1	.2	10.2	.1	100.0
INDUSTRIAL SOLID WASTES	.112	7.3	6.6	2.6	27.6	46.8	6.9	.0	2.2	.0	100.0
ATM EMMISSIONS	8.809	7.5	3.0	2.1	7.9	6.4	.9	1.1	70.3	.8	100.0
WATERBORNE WASTES	3.240	2.0	.4	1.6	3.6	67.5	12.5	.2	12.1	.1	100.0
POST-CONSUMER SOL WASTE	2.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	.889	5.1	1.1	.7	5.8	1.6	.4	1.7	83.0	.6	100.0
ENERGY SOURCE NAT GAS	.425	50.0	5.9	1.0	8.5	33.6	.8	.2	0.0	0.0	100.0
ENERGY SOURCE COAL	.158	12.7	14.9	2.5	43.2	21.6	5.1	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.031	14.6	17.1	0.0	37.6	24.8	5.8	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.056	0.0	0.0	14.7	85.3	0.0	0.0	0.0	0.0	0.0	100.0

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The bottle washing and milk delivery processes account for 60.1 percent of the total energy, 78.9 percent of the water use, 49.0 percent of the industrial solid wastes, 77.0 percent of the atmospheric emissions, and 78.9 percent of the waterborne wastes. It is not that these values are high for thi refillable container, but the basic manufacturing steps are low by comparison with nonrefillable containers. Instead of going through manufacture of the raw materials, resin and container once for each filling of a container, these steps take only one-fiftieth the requirements of a nonrefillable container and make the washing, filling and delivery steps seem high by comparison. Data for the half gallon and half pint 50-trip plastic container systems are given in Tables 19 and 20. The analysis of these systems shows results very similar to the one gallon system.

A summary of the impacts for 1,000 gallons of the 50-trip one gallon, half gallon and half pint containers is given in Table 21. The impacts for the one gallon container are smaller than the half gallon and half pint summaries. The primary reason for the indirect relationship of container size and quantity of impacts is that the smaller containers require more container weight per unit volume of product (milk), and therefore require more energy and materials for each step in the system.

The effect of trip rate on the impact summaries for 1,000 gallons of the gallon refillable plastic container is given in Table 22. The energy requirements show a 71 percent decrease for a 50-trip container over the 5-trip container. However, the energy difference between the 75-trip and 100-trip container is only 5 percent. Therefore, the opportunity for energy savings decreases rapidly after 50 to 75 trips.

The raw materials category shows about the same dependence on trip rate. Water use decreases significantly for the 10- and 20-trip containers and very slowly thereafter. The industrial solid wastes, atmospheric emissions, and waterborne wastes appear to level out after 20 trips.

The data in Table 22 indicate that the greatest improvements in resource and environmental impacts of refilling the plastic container are achieved between 50 to 75 trips; beyond that the decline is only marginal.

D. Nonrefillable Plastic Bottles

1. Overview: The flow diagrams for the three nonrefillable plastic bottle systems are shown in Figures 17, 18, and 19. The raw materials are identical to those described previously for the refillable plastic bottle systems. The plastic resin is shipped to either a custom blow-molding plant or directly to the dairies. About 50 percent of the containers were made in the dairies in 1974.

TABLE 19

IMPACTS FOR 1,000 GALLONS OF THE 50-TRIP REFILLABLE HALF GALLON PLASTIC BOTTLE

INPUTS TO SYSTEMS

NAME	UNITS	HDPE RESIN SYS 11.22 LB	PLS RET HF GAL MFG 11.17 LB	PLS RET HF GAL PKG 13.40 LB	PAPER CLOSURE SYS 10.0 LB	PLS RET HF GAL WASH	PLS RET HF GAL FILL CAP	TRAN HG RET PLS 50 TP SY	PLS RET HF GAL TRAN MILK	PLS RET HF GAL PCS*	TOTAL
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	1.542	5.300	0.000	0.000	0.000	0.000	0.000	6.842
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	1.600	0.000	0.000	0.000	0.000	0.000	1.600
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	1.195	1.286	0.000	0.000	0.000	0.000	2.481
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.072	.019	.010	.103	.025	.004	.024	.738	.009	1.003
ENERGY SOURCE NAT GAS	MILL BTU	.335	.049	.006	.073	.282	.004	.001	0.000	0.000	.751
ENERGY SOURCE COAL	MILL BTU	.032	.045	.006	.136	.060	.010	0.000	0.000	0.000	.287
ENERGY SOURCE MISC	MILL BTU	.007	.010	0.000	.023	.013	.002	0.000	0.000	0.000	.056
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.013	.095	0.000	0.000	0.000	0.000	0.000	.108
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	.629	0.000	.155	.784	1.997	0.000	0.000	0.000	0.000	3.564
ENERGY PROCESS	MIL BTU	.171	.123	.035	.428	.380	.021	0.000	0.000	0.000	1.158
ENERGY TRANSPORT	MIL BTU	.006	0.000	.000	.003	.000	0.000	.025	.738	.009	.780
ENERGY OF MATL RESOURCE	MIL BTU	.249	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	.270
WATER VOLUME	THOU GAL	.021	.039	.001	.114	.597	.000	.001	.044	.001	.817

OUTPUTS FROM SYSTEMS

NAME	UNITS	HDPE RESIN SYS 11.22 LB	PLS RET HF GAL MFG 11.17 LB	PLS RET HF GAL PKG 13.40 LB	PAPER CLOSURE SYS 10.0 LB	PLS RET HF GAL WASH	PLS RET HF GAL FILL CAP	TRAN HG RET PLS 50 TP SY	PLS RET HF GAL TRAN MILK	PLS RET HF GAL PCS*	TOTAL
SOLID WASTES PROCESS	POUND	.267	.056	.148	1.776	3.110	.400	0.000	0.000	0.000	5.757
SOLID WASTES FUEL COMB	POUND	.186	.265	.100	1.087	.351	.059	.006	.179	.002	2.234
SOLID WASTES MINING	POUND	.505	.723	.087	1.678	.976	.161	0.000	0.000	0.000	4.129
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.372	2.647
ATMOS PARTICULATES	POUND	.044	.057	.086	.201	.091	.012	.003	.078	.001	.563
ATMOS NITROGEN OXIDES	POUND	.200	.113	.036	.298	.265	.022	.059	1.169	.010	2.169
ATMOS HYDROCARBONS	POUND	.557	.066	.022	.138	.294	.008	.021	.670	.010	1.784
ATMOS SULFUR OXIDES	POUND	.201	.248	.123	.682	.331	.055	.010	.220	.002	1.872
ATMOS CARBON MONOXIDE	POUND	.042	.016	.012	.061	.045	.003	.067	3.840	.101	4.165
ATMOS ALDEHYDES	POUND	.000	.000	.000	.001	.001	.000	.001	.047	.001	.050
ATMOS OTHER ORGANICS	POUND	.001	.000	.018	.001	.001	.000	.002	.143	.010	.186
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	.004	.000	0.000	0.000	0.000	0.000	.004
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	.000	0.000	.000	.002	.000	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	.000	.000	0.000	.000	.010	.000	.010
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	.006	.010	0.000	0.000	0.000	0.000	.016
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.040	.011	.012	.063	.048	.001	.012	.382	.005	.574
WATERBORNE BOD	POUND	.003	.000	.045	.044	.069	.160	.000	.001	.000	.322
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.001	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE COD	POUND	.020	.000	.000	.000	.000	.000	.000	.004	.000	.024
WATERBORNE SUSP SOLIDS	POUND	.006	.000	.021	.078	.103	.240	.000	.002	.000	.451
WATERBORNE ACID	POUND	.010	.014	.001	.039	.018	.003	.000	.001	.000	.085
WATERBORNE METAL ION	POUND	.002	.003	.000	.009	.005	.001	.000	.000	.000	.021
WATERBORNE CHEMICALS	POUND	0.000	0.000	.002	0.000	0.000	0.000	0.000	0.000	0.000	.002
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	1.960	0.000	0.000	0.000	0.000	1.960
WATERBORNE CHROMIUM	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

SUMMARY OF ENVIRONMENTAL IMPACTS

NAME	UNITS	HDPE RESIN SYS 11.22 LB	PLS RET HF GAL MFG 11.17 LB	PLS RET HF GAL PKG 13.40 LB	PAPER CLOSURE SYS 10.0 LB	PLS RET HF GAL WASH	PLS RET HF GAL FILL CAP	TRAN HG RET PLS 50 TP SY	PLS RET HF GAL TRAN MILK	PLS RET HF GAL PCS*	TOTAL
RAW MATERIALS	POUNDS	.629	0.000	1.696	8.879	3.283	0.000	0.000	0.000	0.000	14.487
ENERGY	MIL BTU	.446	.123	.036	.431	.380	.021	.025	.738	.009	2.208
WATER	THOU GAL	.021	.039	.001	.114	.597	.000	.001	.044	.001	.817
INDUSTRIAL SOLID WASTES	CUBIC FT	.013	.014	.005	.061	.060	.008	.000	.002	.000	.164
ATM EMMISSIONS	POUNDS	1.044	.501	.297	1.391	1.027	.101	.164	6.190	.134	10.821
WATERBORNE WASTES	POUNDS	.102	.028	.081	.233	2.222	.405	.013	.391	.005	3.440
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.372	2.647
ENERGY SOURCE PETROLEUM	MIL BTU	.072	.019	.010	.103	.025	.004	.024	.738	.009	1.003
ENERGY SOURCE NAT GAS	MIL BTU	.335	.049	.006	.073	.282	.004	.001	0.000	0.000	.751
ENERGY SOURCE COAL	MIL BTU	.032	.045	.006	.136	.060	.010	0.000	0.000	0.000	.288
ENERGY SOURCE NUCL HYDRO	MIL BTU	.007	.010	0.000	.023	.013	.002	0.000	0.000	0.000	.056
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.013	.095	0.000	0.000	0.000	0.000	0.000	.108

INDEX OF ENVIRONMENTAL IMPACTS

NAME	STANDARD VALUES	HDPE RESIN SYS 11.22 LB	PLS RET HF GAL MFG 11.17 LB	PLS RET HF GAL PKG 13.40 LB	PAPER CLOSURE SYS 10.0 LB	PLS RET HF GAL WASH	PLS RET HF GAL FILL CAP	TRAN HG RET PLS 50 TP SY	PLS RET HF GAL TRAN MILK	PLS RET HF GAL PCS*	TOTAL
RAW MATERIALS	14.487	4.3	0.0	11.7	61.3	22.7	0.0	0.0	0.0	0.0	100.0
ENERGY	2.208	20.2	5.6	1.6	19.5	17.2	.9	1.2	33.5	.4	100.0
WATER	.817	2.5	4.8	.1	13.9	73.0	.0	.2	5.4	.1	100.0
INDUSTRIAL SOLID WASTES	.164	7.9	8.5	3.4	37.5	36.6	5.1	.0	1.4	.0	100.0
ATM EMMISSIONS	10.821	9.7	4.6	2.7	12.9	9.5	.9	1.5	57.2	1.2	100.0
WATERBORNE WASTES	3.440	2.9	.8	2.3	6.7	63.9	11.8	.4	11.3	.1	100.0
POST-CONSUMER SOL WASTE	2.647	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	127.4	100.0
ENERGY SOURCE PETROLEUM	1.003	7.2	1.9	1.0	10.3	2.5	.4	2.4	73.6	.9	100.0
ENERGY SOURCE NAT GAS	.751	44.7	6.5	.9	9.7	37.6	.5	.1	0.0	0.0	100.0
ENERGY SOURCE COAL	.288	10.9	15.6	2.1	47.2	20.7	3.5	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYDRO	.056	12.6	18.1	0.0	41.4	23.9	4.0	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.108	0.0	0.0	12.0	88.0	0.0	0.0	0.0	0.0	0.0	100.0

TABLE 20

IMPACTS FOR 1,000 GALLONS OF THE 50-TRIP REFILLABLE HALF PINT PLASTIC BOTTLE

NAME	UNITS	HDPE RESIN SYS 24.23 LB	PLS RET HF PINT MFG 24.11 LB	PLS RET HF PINT PKG 28.93 LB	PAPER CLOSURE SYS 22.93 LB	RET PLS HF PINT WASH	RET PLS HF PINT FILL CAP	TRAN HF RET PLS 50 TP SY	RET PLS HF PINT MILK TRAN	RET PLS HF PINT PCSW	TOTAL
INPUTS TO SYSTEMS											
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	3.327	12.193	0.000	0.000	0.000	0.000	0.000	[illegible]
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	3.669	0.000	0.000	0.000	0.000	0.000	3.669
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.030
MATERIAL SALT	POUND	0.000	0.000	0.000	2.740	1.284	0.000	0.000	0.000	0.000	4.024
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.156	.031	.022	.237	[illegible]	.004	.056	.567	.010	1.168
ENERGY SOURCE NAT GAS	MILL BTU	.724	.096	.014	.167	1.119	.006	.002	0.000	0.000	2.126
ENERGY SOURCE COAL	MILL BTU	.048	.076	.013	.312	.213	.010	0.000	0.000	0.000	.492
ENERGY SOURCE MISC	MILL BTU	.019	.017	0.000	.046	.048	.002	0.000	0.000	0.000	.136
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.028	.219	0.000	0.000	0.000	0.000	0.000	[illegible]
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]
MATERIAL PROCESS ADD	POUNDS	1.397	0.000	.334	1.797	1.959	0.000	0.000	0.000	0.000	[illegible]
ENERGY PROCESS	MIL BTU	.370	.220	.074	.982	1.468	.021	0.000	0.000	0.000	3.137
ENERGY TRANSPORT	MIL BTU	.012	0.000	.000	.007	.000	0.000	.056	.567	.010	.632
ENERGY OF MATL RESOURCE	MIL BTU	.501	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	[illegible]
WATER VOLUME	THOU GAL	.044	.076	.002	.261	2.379	.000	.003	.032	.001	2.794
OUTPUTS FROM SYSTEMS											
SOLID WASTES PROCESS	POUND	.577	.121	.320	4.068	3.110	.400	0.000	0.000	0.000	[illegible]
SOLID WASTES FUEL COMB	POUND	.401	.444	.217	2.493	1.243	.059	.013	.130	.002	[illegible]
SOLID WASTES MINING	POUND	1.091	1.200	.109	3.067	3.433	.161	0.000	0.000	0.000	[illegible]
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.540	3.540
ATMOS PARTICULATES	POUND	.099	.095	.186	.460	.287	.012	.007	.058	.001	1.207
ATMOS NITROGEN OXIDES	POUND	.431	.197	.377	.083	1.003	.022	.131	1.007	.010	[illegible]
ATMOS HYDROCARBONS	POUND	1.206	.125	.047	.316	1.156	.008	.044	.467	.010	[illegible]
ATMOS SULFUR OXIDES	POUND	.433	.016	.205	1.566	1.103	.055	.122	.176	.002	[illegible]
ATMOS CARBON MONOXIDE	POUND	.090	.028	.027	.139	.175	.003	.140	2.300	.144	[illegible]
ATMOS ALDEHYDES	POUND	.001	.000	.000	.001	.003	.000	.002	.028	.001	[illegible]
ATMOS OTHER ORGANICS	POUND	.001	.001	.039	.003	.006	.000	.005	.046	.017	[illegible]
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	.009	.000	0.000	0.000	0.000	0.000	[illegible]
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	.000	0.000	.000	.001	.000	[illegible]
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
ATMOS LEAD	POUND	.000	0.000	.000	.000	.000	0.000	.000	.005	.000	[illegible]
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	0.000	0.000	0.000	[illegible]
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	.014	.010	0.000	0.000	0.000	0.000	.023
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.129	.020	.026	.144	.221	.001	.027	.278	.006	.852
WATERBORNE BOD	POUND	.006	.000	.098	.101	.069	.160	.000	.001	.000	.436
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE OIL	POUND	.001	.000	.000	.000	.000	.000	.000	.000	.000	.002
WATERBORNE COD	POUND	.043	.000	.000	.000	.000	.000	.000	.003	.000	[illegible]
WATERBORNE SUSP SOLIDS	POUND	.014	.000	.045	.179	.103	.243	.000	.002	.000	.586
WATERBORNE ACID	POUND	.021	.023	.002	.049	.065	.003	.000	.001	.000	[illegible]
WATERBORNE METAL ION	POUND	.005	.006	.001	.021	.016	.001	.000	.000	.000	.050
WATERBORNE CHEMICALS	POUND	0.000	0.000	.004	0.000	0.000	0.000	0.000	0.000	0.000	.004
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	1.940	0.000	0.000	0.000	0.000	1.940
WATERBORNE CHROMIUM	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS											
RAW MATERIALS	POUNDS	1.397	0.000	3.661	20.359	3.243	0.000	0.000	0.000	0.000	28.661
ENERGY	MIL BTU	.964	.220	.077	.989	1.468	.021	.056	.567	.010	6.351
WATER	THOU GAL	.044	.076	.002	.241	2.379	.000	.003	.032	.001	2.794
INDUSTRIAL SOLID WASTES	CUBIC FT	.028	.024	.010	.140	.195	.008	.000	.007	.000	.318
ATM EMMISSIONS	POUNDS	2.255	.862	.641	3.190	3.820	.101	.363	4.104	.146	15.526
WATERBORNE WASTES	POUNDS	.220	.049	.176	.535	2.435	.605	.028	.205	.006	4.138
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.540	3.540
ENERGY SOURCE PETROLEUM	MIL BTU	.156	.031	.022	.237	[illegible]	.004	.056	.567	.010	1.168
ENERGY SOURCE NAT GAS	MIL BTU	.724	.096	.014	.167	1.119	.006	.002	0.000	0.000	2.126
ENERGY SOURCE COAL	MIL BTU	.048	.076	.013	.312	.213	.010	0.000	0.000	0.000	.492
ENERGY SOURCE NUCL HYDRO	MIL BTU	.015	.017	0.000	.056	.048	.002	0.000	0.000	0.000	.136
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.028	.219	0.000	0.000	0.000	0.000	0.000	.264
INDEX OF ENVIRONMENTAL IMPACTS	STANDARD VALUES										
RAW MATERIALS	28.661	4.7	0.0	12.8	71.0	11.5	0.0	0.0	0.0	0.0	100.0
ENERGY	6.351	22.1	5.1	1.8	22.7	33.7	.5	1.3	17.6	.2	100.0
WATER	2.794	1.6	2.7	.1	9.3	85.0	.0	.1	1.2	.0	100.0
INDUSTRIAL SOLID WASTES	.318	8.8	7.5	3.1	44.2	33.1	2.6	.1	.4	.0	100.0
ATM EMMISSIONS	15.526	14.5	5.6	4.1	20.5	24.6	.6	2.3	26.5	1.2	100.0
WATERBORNE WASTES	4.138	5.3	1.2	4.2	12.9	58.8	9.8	.7	4.9	.1	100.0
POST-CONSUMER SOL WASTE	3.540	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	1.168	13.4	2.7	1.9	20.4	7.6	.6	4.7	47.6	.4	100.0
ENERGY SOURCE NAT GAS	2.126	34.1	4.5	.7	7.9	52.6	.2	.1	0.0	0.0	100.0
ENERGY SOURCE COAL	.492	9.8	15.9	1.9	65.1	30.8	1.6	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYDRO	.136	11.3	12.5	0.0	39.2	35.3	1.7	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.264	0.0	0.0	11.3	48.7	0.0	0.0	0.0	0.0	0.0	100.0

TABLE 21

SUMMARY OF IMPACTS FOR 1,000 GALLONS OF EACH 50-TRIP REFILLABLE PLASTIC SYSTEM

Impacts	Gallon	Half gallon	Half pint
Raw materials, lb	9.20	14.49	28.66
Energy, 10^6 Btu	1.56	2.21	4.35
Water, 10^3 gal.	0.44	0.82	2.80
Industrial solid waste, cu ft	0.11	0.16	0.32
Atmospheric emissions, lb	8.81	10.82	15.53
Waterborne wastes, lb	3.24	3.48	4.14
Postconsumer solid waste, cu ft	2.00	2.65	3.54
Petroleum, 10^6 Btu	0.89	1.0	1.15
Natural gas, 10^6 Btu	0.42	0.75	2.13
Coal, 10^6 Btu	0.16	0.29	0.69
Nuclear hydropower, 10^6 Btu	0.03	0.06	0.14
Wood Wastes, 10^6 Btu	0.06	0.11	0.25

Source: Midwest Research Institute.

TABLE 22

COMPARISON OF IMPACTS VERSUS TRIP RATE FOR 1,000 GALLONS OF THE REFILLABLE PLASTIC CONTAINER SYSTEM

Impacts	Trip rate					
	5	10	20	50	75	100
Raw materials, lb	21.88	14.83	11.31	9.20	8.73	8.50
Energy, 10^6 Btu	4.98	3.08	2.13	1.56	1.44	1.37
Water, 10^3 gal.	0.69	0.55	0.48	0.44	0.43	0.42
Industrial solid waste, cu ft	0.27	0.18	0.14	0.11	0.11	0.10
Atmospheric emissions, lb	19.80	13.70	10.67	8.81	8.41	8.21
Waterborne wastes, lb	4.08	3.61	3.38	3.24	3.21	3.19
Postconsumer solid waste, cu ft	16.24	8.46	5.06	2.00	1.60	1.29

Source: Midwest Research Institute.

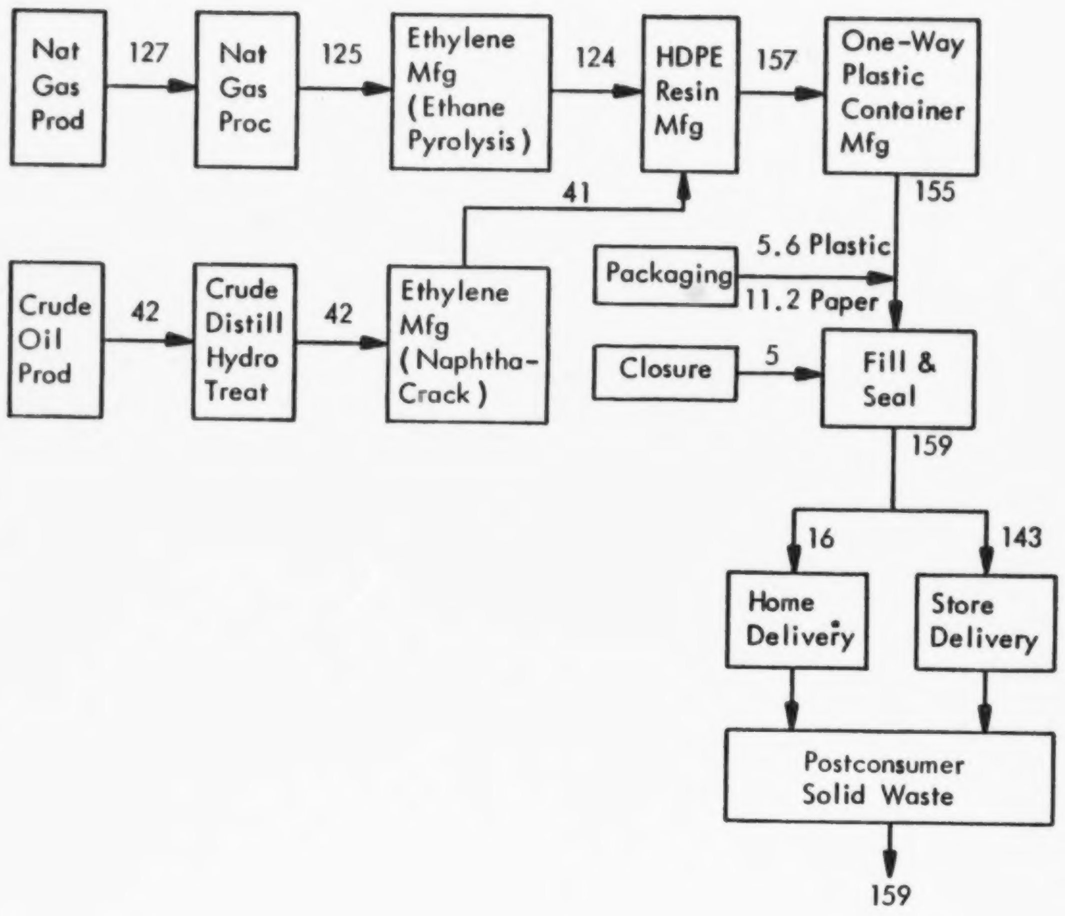

Nat Gas Prod
127
Nat Gas Proc
125
Ethylene Mfg (Ethane Pyrolysis)
124
HDPE Resin Mfg
157
One-Way Plastic Container Mfg
155
Crude Oil Prod
42
Crude Distill Hydro Treat
42
Ethylene Mfg (Naphtha-Crack)
41
Packaging
5.6 Plastic
11.2 Paper
Closure
5
Fill & Seal
159
16
143
Home Delivery
Store Delivery
Postconsumer Solid Waste
159

Figure 17. Flow diagram shows delivery of 1,000 gallons of milk in nonrefillable plastic gallon bottles (in pounds).

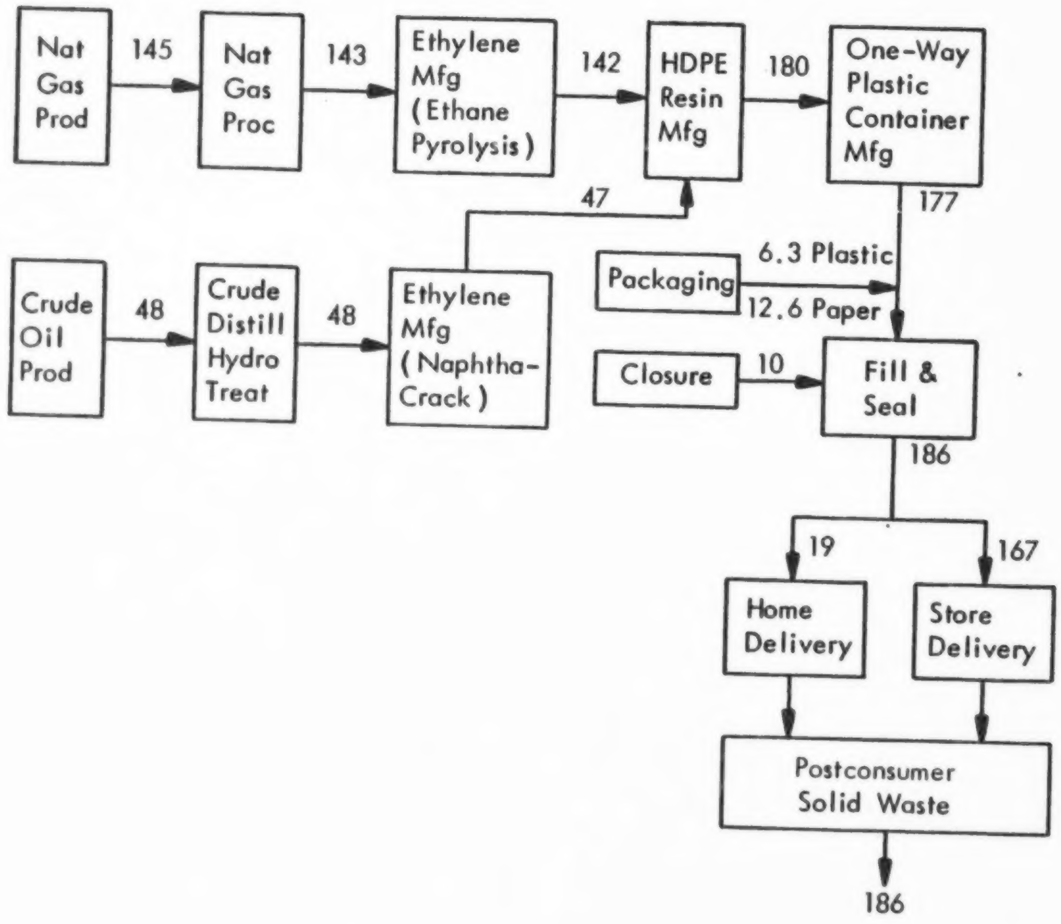

Nat Gas Prod
145
Nat Gas Proc
143
Ethylene Mfg (Ethane Pyrolysis)
142
HDPE Resin Mfg
180
One-Way Plastic Container Mfg
177
Crude Oil Prod
48
Crude Distill Hydro Treat
48
Ethylene Mfg (Naphtha-Crack)
47
Packaging
6.3 Plastic
12.6 Paper
Closure
10
Fill & Seal
186
19
167
Home Delivery
Store Delivery
Postconsumer Solid Waste
186

Figure 18. Flow diagram shows delivery of 1,000 gallons of milk in nonrefillable plastic half gallon bottles (in pounds).

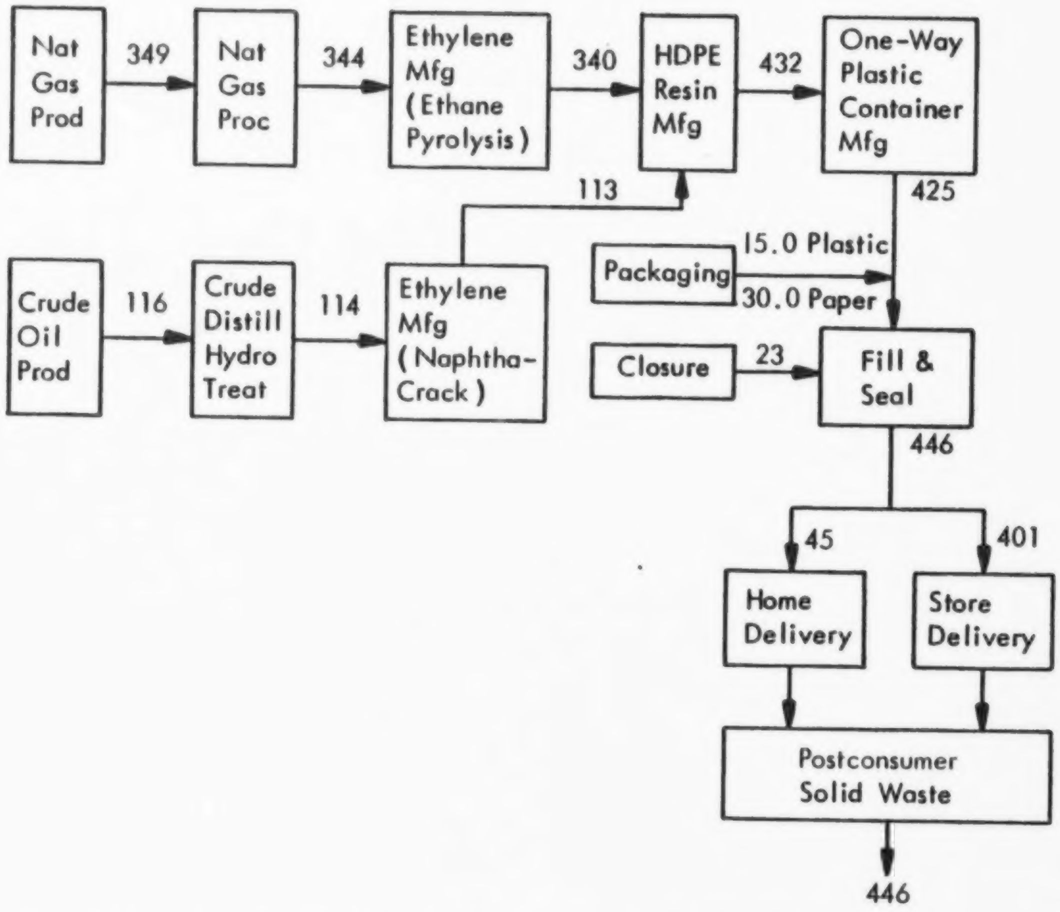

Nat Gas Prod
349
Nat Gas Proc
344
Ethylene Mfg (Ethane Pyrolysis)
340
HDPE Resin Mfg
432
One-Way Plastic Container Mfg
425
Crude Oil Prod
116
Crude Distill Hydro Treat
114
Ethylene Mfg (Naphtha-Crack)
113
Packaging
15.0 Plastic
30.0 Paper
Closure
23
Fill & Seal
446
45
401
Home Delivery
Store Delivery
Postconsumer Solid Waste
446

Figure 19. Flow diagram for delivery of 1,000 gallons of milk in nonrefillable plastic half pint bottles (in pounds).

2. Profile analysis: The resource and environmental profile data for 1,000 gallons of the nonrefillable plastic gallon bottle system are presented in Table 23. The system is divided into eight separate processes. The high density polyehtylene resin system has the highest impacts in each impact category except postconsumer solid waste. The resin system accounts for 71.3 percent of the energy for the entire bottle system. The energy of material resource (the energy content of the crude oil and natural gas raw materials) represents 60 percent of the resin system energy and 43 percent of the total nonrefillable plastic bottle system energy. Table 24 below shows the processes having the first and second highest impacts for each impact category. The table shows that the processes which contribute most heavily to the nonrefillable plastic bottle resource and environmental profile are the resin system, the packaging system, milk delivery and container manufacturing.

The impact summaries for the half gallon and half pint nonrefillable plastic containers are given in Tables 25 and 26. In the analysis of the half gallon system, the resin subsystem again shows the highest impacts in each impact category. The half gallon container manufacturing step contributes heavily to the water and industrial solid waste categories. Milk delivery requires about 7 percent of the total bottle system energy.

The impact analysis of the half pint container shows the resin system to predominate in each category. The milk transportation process is less for the half pint container since only store delivery was considered.

Table 27 contains a summary of resource and environmental impacts for delivering 1,000 gallons of milk in each nonrefillable plastic container size. The impacts increase as the size of the container decreases. The reason for this relationship is that more raw materials are required per unit volume of milk as the capacity of the container decreases. The half gallon container requires 1.15 times the energy of the gallon container and the half pint requires 2.58 times the energy of the gallon container system. Therefore, from a resource and environmental viewpoint, the one gallon container has a more favorable profile than the two smaller containers.

TABLE 23

IMPACTS FOR 1,000 GALLONS OF THE NONREFILLABLE GALLON PLASTIC BOTTLE SYSTEM

NAME	UNITS	HDPE RESIN SYS 157.4 LB	OW PLS CONT MFG 154.3 LB	PKG FOR EMPTY CONT	PLASTIC CLOSURE SYS 5.0 LB	FILL SEAL THOU GAL	TRAN FOR MILK DELIVERY THOU GAL	TRAN GAL OW PLS SYS	POST CONS SLD WSTE 154.3 LB	TOTAL
INPUTS TO SYSTEMS										
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	7.679	0.000	0.000	0.000	0.000	0.000	7.679
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	1.011	.130	.091	.044	.005	.738	.212	.201	2.432
ENERGY SOURCE NAT GAS	MILL BTU	4.706	.131	.204	.164	.005	0.000	.015	0.000	5.226
ENERGY SOURCE COAL	MILL BTU	.443	.315	.058	.042	.012	0.000	0.000	0.000	.869
ENERGY SOURCE MISC	MILL BTU	.100	.071	.006	.009	.003	0.000	0.000	0.000	.190
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.064	0.000	0.000	0.000	0.000	0.000	.064
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	8.817	0.000	.915	.286	0.000	0.000	0.000	0.000	10.018
ENERGY PROCESS	MIL BTU	2.405	.647	.287	.134	.025	0.000	0.000	0.000	3.496
ENERGY TRANSPORT	MIL BTU	.078	0.000	.004	.003	0.000	.738	.227	.201	1.251
ENERGY OF MATL RESOURCE	MIL BTU	3.777	0.000	.133	.122	0.000	0.000	0.000	0.000	4.032
WATER VOLUME	THOU GAL	.288	.257	.025	.018	.000	.044	.013	.012	.657
OUTPUTS FROM SYSTEMS										
SOLID WASTES PROCESS	POUND	3.750	3.086	.898	.222	.400	0.000	0.000	0.000	8.355
SOLID WASTES FUEL COMB	POUND	2.604	1.852	.660	.246	.072	.179	.050	.050	5.713
SOLID WASTES MINING	POUND	7.088	5.044	.871	.670	.196	0.000	0.000	0.000	13.869
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	75.430	75.430
ATMOS PARTICULATES	POUND	.619	.392	.470	.054	.015	.078	.027	.021	1.677
ATMOS NITROGEN OXIDES	POUND	2.802	.682	.303	.150	.026	1.169	.528	.215	5.876
ATMOS HYDROCARBONS	POUND	7.818	.265	.394	.277	.010	.670	.201	.218	9.854
ATMOS SULFUR OXIDES	POUND	2.815	1.732	.774	.242	.067	.220	.088	.052	5.990
ATMOS CARBON MONOXIDE	POUND	.582	.084	.086	.026	.003	3.840	.668	1.693	6.983
ATMOS ALDEHYDES	POUND	.004	.001	.001	.000	.000	.047	.010	.017	.081
ATMOS OTHER ORGANICS	POUND	.009	.002	.089	.000	.000	.153	.026	.108	.386
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	0.000	.002	.001	.001	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	.000	0.000	.010	.001	.004	.015
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.839	.037	.092	.030	.001	.382	.109	.107	1.597
WATERBORNE BOD	POUND	.039	.000	.227	.001	.160	.001	.000	.000	.429
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.010	.000	.000	.000	.000	.000	.000	.000	.011
WATERBORNE COD	POUND	.281	.000	.011	.009	.000	.004	.001	.001	.308
WATERBORNE SUSP SOLIDS	POUND	.091	.000	.108	.003	.240	.002	.001	.001	.445
WATERBORNE ACID	POUND	.136	.097	.013	.013	.004	.001	.000	.000	.263
WATERBORNE METAL ION	POUND	.034	.024	.003	.003	.001	.000	.000	.000	.066
WATERBORNE CHEMICALS	POUND	0.000	0.000	.008	0.000	0.000	0.000	0.000	0.000	.008
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS	UNITS									
RAW MATERIALS	POUNDS	8.817	0.000	8.594	.286	0.000	0.000	0.000	0.000	17.697
ENERGY	MIL BTU	6.260	.647	.423	.259	.025	.738	.227	.201	8.781
WATER	THOU GAL	.288	.257	.025	.018	.000	.044	.013	.012	.657
INDUSTRIAL SOLID WASTES	CUBIC FT	.181	.135	.033	.015	.009	.002	.001	.001	.377
ATM EMMISSIONS	POUNDS	14.649	3.158	2.119	.751	.122	6.190	1.548	2.330	30.865
WATERBORNE WASTES	POUNDS	1.428	.159	.464	.060	.406	.391	.111	.110	3.130
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	75.430	75.430
ENERGY SOURCE PETROLEUM	MIL BTU	1.011	.130	.091	.044	.005	.738	.212	.201	2.432
ENERGY SOURCE NAT GAS	MIL BTU	4.706	.131	.204	.164	.005	0.000	.015	0.000	5.226
ENERGY SOURCE COAL	MIL BTU	.443	.315	.058	.042	.012	0.000	0.000	0.000	.869
ENERGY SOURCE NUCL HYPWR	MIL BTU	.100	.071	.006	.009	.003	0.000	0.000	0.000	.190
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.064	0.000	0.000	0.000	0.000	0.000	.064
INDEX OF ENVIRONMENTAL IMPACTS	STANDARD VALUES									
RAW MATERIALS	17.697	49.8	0.0	48.6	1.6	0.0	0.0	0.0	0.0	100.0
ENERGY	8.781	71.3	7.4	4.8	3.0	.3	8.4	2.6	2.3	100.0
WATER	.657	43.8	39.1	3.7	2.7	.1	6.8	1.9	1.9	100.0
INDUSTRIAL SOLID WASTES	.377	48.1	35.7	8.7	4.1	2.4	.5	.2	.2	100.0
ATM EMMISSIONS	30.865	47.5	10.2	6.9	2.4	.4	20.1	5.0	7.5	100.0
WATERBORNE WASTES	3.130	45.6	5.1	14.8	1.9	13.0	12.5	3.6	3.5	100.0
POST-CONSUMER SOL WASTE	75.430	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	2.432	41.6	5.3	3.7	1.8	.2	30.4	8.7	8.3	100.0
ENERGY SOURCE NAT GAS	5.226	90.1	2.5	3.9	3.1	.1	0.0	.3	0.0	100.0
ENERGY SOURCE COAL	.869	50.9	36.2	6.6	4.8	1.4	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.190	52.8	37.6	3.2	5.0	1.5	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.064	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0

TABLE 24

IMPACT ANALYSIS--NONREFILLABLE PLASTIC GALLON BOTTLE

Impact category	Processes with highest impacts (%)	Processes with second highest impacts (%)	Total percent for two highest processes
Raw materials	Resin system--49.8	Packaging--48.6	98.4
Energy	Resin system--72.6	Milk delivery--8.6	81.2
Water	Resin system--44.5	Container Manufacture--39.7	84.2
Industrial solid wastes	Resin system--48.2	Container Manufacture--35.8	84.0
Atmospheric emissions	Resin system--50.1	Milk delivery--21.2	71.3
Waterborne wastes	Resin system--46.9	Packaging--15.2	62.1
Postconsumer solid wastes	PCSW--100.0		100.0

TABLE 25

IMPACTS FOR 1,000 GALLONS OF THE NONREFILLABLE PLASTIC HALF GALLON BOTTLE SYSTEM

NAME	UNITS	HDPE RESIN SYS 180.0 LB	OW PLS HF GAL MFG 176.4 LB	OW PLS HF GAL PKG	HDPE CLOSURE SYS 10.0 LB	OW PLS HF GAL FILL CAP	OW PLS HF GAL MILK DELIVERY	TRAN HGAL OW PLS SYS	OW PLS HF GAL PCSW 176.4 LB	TOTAL
INPUTS TO SYSTEMS										
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	8.758	0.000	0.000	0.000	0.000	0.000	8.754
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	1.156	.149	.106	.088	.004	.738	.248	.202	2.690
ENERGY SOURCE NAT GAS	MILL BTU	5.382	.151	.233	.328	.004	0.000	.018	0.000	6.116
ENERGY SOURCE COAL	MILL BTU	.506	.363	.066	.084	.010	0.000	0.000	0.000	1.028
ENERGY SOURCE MISC	MILL BTU	.114	.082	.007	.019	.002	0.000	0.000	0.000	.225
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.074	0.000	0.000	0.000	0.000	0.000	.074
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	10.083	0.000	1.044	.571	0.000	0.000	0.000	0.000	11.698
ENERGY PROCESS	MIL BTU	2.750	.745	.327	.269	.021	0.000	0.000	0.000	4.111
ENERGY TRANSPORT	MIL BTU	.089	0.000	.004	.005	0.000	.738	.266	.202	1.305
ENERGY OF MATL RESOURCE	MIL BTU	4.319	0.000	.152	.245	0.000	0.000	0.000	0.000	4.716
WATER VOLUME	THOU GAL	.329	.259	.028	.035	.000	.044	.015	.013	.724
OUTPUTS FROM SYSTEMS										
SOLID WASTES PROCESS	POUND	4.289	3.528	1.024	.443	.470	0.000	0.000	0.000	9.713
SOLID WASTES FUEL COMB	POUND	2.978	2.133	.752	.492	.059	.179	.058	.050	6.701
SOLID WASTES MINING	POUND	8.106	5.807	.993	1.340	.161	0.000	0.000	0.000	16.407
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	75.816	75.799
ATMOS PARTICULATES	POUND	.707	.452	.536	.109	.012	.078	.032	.021	1.947
ATMOS NITROGEN OXIDES	POUND	3.205	.785	.346	.301	.022	1.169	.619	.216	6.662
ATMOS HYDROCARBONS	POUND	8.941	.306	.449	.553	.008	.670	.235	.219	11.341
ATMOS SULFUR OXIDES	POUND	3.219	1.994	.883	.485	.055	.220	.103	.053	7.011
ATMOS CARBON MONOXIDE	POUND	.666	.097	.098	.052	.003	3.840	.781	1.734	7.270
ATMOS ALDEHYDES	POUND	.005	.001	.001	.000	.000	.047	.011	.017	.083
ATMOS OTHER ORGANICS	POUND	.010	.002	.102	.001	.000	.153	.029	.115	.411
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	0.000	.002	.001	.001	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	.000	0.000	.010	.002	.004	.016
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.959	.043	.104	.061	.001	.382	.127	.108	1.785
WATERBORNE BOD	POUND	.044	.000	.259	.003	.160	.001	.000	.000	.468
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.011	.000	.000	.001	.000	.000	.000	.000	.013
WATERBORNE COD	POUND	.321	.000	.013	.018	.000	.004	.001	.001	.359
WATERBORNE SUSP SOLIDS	POUND	.104	.000	.124	.006	.240	.002	.001	.001	.478
WATERBORNE ACID	POUND	.155	.111	.019	.026	.003	.001	.000	.000	.311
WATERBORNE METAL ION	POUND	.039	.028	.004	.006	.001	.000	.000	.000	.078
WATERBORNE CHEMICALS	POUND	0.000	0.000	.010	0.000	0.000	0.000	0.000	0.000	.010
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
RAW MATERIALS	POUNDS	10.083	0.000	9.801	.571	0.000	0.000	0.000	0.000	20.452
ENERGY	MIL BTU	7.159	.745	.483	.519	.021	.738	.266	.202	10.132
WATER	THOU GAL	.329	.259	.028	.035	.000	.044	.015	.013	.724
INDUSTRIAL SOLID WASTES	CUBIC FT	.208	.155	.037	.031	.009	.002	.001	.001	.443
ATM EMMISSIONS	POUNDS	16.752	3.636	2.415	1.501	.101	6.190	1.811	2.375	34.785
WATERBORNE WASTES	POUNDS	1.633	.183	.529	.120	.405	.391	.130	.110	3.503
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	75.816	75.799
ENERGY SOURCE PETROLEUM	MIL BTU	1.156	.149	.104	.088	.004	.738	.248	.202	2.690
ENERGY SOURCE NAT GAS	MIL BTU	5.382	.151	.233	.328	.004	0.000	.018	0.000	6.116
ENERGY SOURCE COAL	MIL BTU	.506	.363	.066	.084	.010	0.000	0.000	0.000	1.028
ENERGY SOURCE NUCL HYPWR	MIL BTU	.114	.082	.007	.019	.002	0.000	0.000	0.000	.225
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.074	0.000	0.000	0.000	0.000	0.000	.074
INDEX OF ENVIRONMENTAL IMPACTS	STANDARD VALUES									
RAW MATERIALS	20.452	49.3	0.0	47.9	2.8	0.0	0.0	0.0	0.0	100.0
ENERGY	10.132	70.7	7.4	4.8	5.1	.2	7.3	2.6	2.0	100.0
WATER	.724	45.5	35.8	3.9	4.9	.0	6.1	2.0	1.7	100.0
INDUSTRIAL SOLID WASTES	.443	46.8	34.9	8.4	6.9	2.0	.5	.2	.2	100.0
ATM EMMISSIONS	34.785	48.2	10.5	6.9	4.3	.3	17.8	5.2	6.8	100.0
WATERBORNE WASTES	3.503	46.6	5.2	15.1	3.4	11.6	11.2	3.7	3.2	100.0
POST-CONSUMER SOL WASTE	75.799	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	2.690	43.0	5.6	3.9	3.3	.2	27.5	9.2	7.5	100.0
ENERGY SOURCE NAT GAS	6.116	88.0	2.5	3.8	5.4	.1	0.0	.3	0.0	100.0
ENERGY SOURCE COAL	1.028	49.2	35.3	6.4	8.1	1.0	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.225	50.9	36.5	3.1	8.4	1.0	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.074	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0

TABLE 26

IMPACTS FOR 1,000 GALLONS OF THE NONREFILLABLE PLASTIC HALF PINT BOTTLE SYSTEM

		HDPE RESIN SYS 431.0 LB	OW PLS HF PINT MFG 422.0 LB	OW PLS HF PINT PKG	PAPER CLOSURE SYS 22.93 LB	OW PLS HF PINT FILL CAP	OW PLS HF PINT MILK DEL	TRAN HPT OW PLS SYS	OW PLS HF PINT PCSW 422.0 LB	TOTAL
INPUTS TO SYSTEMS										
NAME	UNITS									
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	20.942	12.153	0.000	0.000	0.000	0.000	33.095
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	3.669	0.000	0.000	0.000	0.000	3.669
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	2.740	0.000	0.000	0.000	0.000	2.740
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	2.768	.359	.248	.237	.039	.547	.592	.214	5.005
ENERGY SOURCE NAT GAS	MILL BTU	12.887	.363	.557	.167	.040	0.000	.043	0.000	14.056
ENERGY SOURCE COAL	MILL BTU	1.212	.872	.157	.312	.095	0.000	0.000	0.000	2.650
ENERGY SOURCE MISC	MILL BTU	.274	.197	.017	.054	.022	0.000	0.000	0.000	.563
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.176	.219	0.000	0.000	0.000	0.000	.394
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	24.144	0.000	2.496	1.797	0.000	0.000	0.000	0.000	28.437
ENERGY PROCESS	MIL BTU	6.585	1.791	.782	.982	.196	0.000	0.000	0.000	10.336
ENERGY TRANSPORT	MIL BTU	.214	0.000	.010	.007	0.000	.547	.635	.214	1.626
ENERGY OF MATL RESOURCE	MIL BTU	10.342	0.000	.362	.001	0.000	0.000	0.000	0.000	10.706
WATER VOLUME	THOU GAL	.789	.915	.067	.261	.003	.032	.035	.013	2.115
OUTPUTS FROM SYSTEMS										
NAME	UNITS									
SOLID WASTES PROCESS	POUND	10.269	8.440	2.448	4.068	.506	0.000	0.000	0.000	25.731
SOLID WASTES FUEL COMB	POUND	7.131	5.130	1.799	2.493	.562	.130	.139	.053	17.437
SOLID WASTES MINING	POUND	19.410	13.971	2.375	3.847	1.529	0.000	0.000	0.000	41.131
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	79.564	79.564
ATMOS PARTICULATES	POUND	1.694	1.086	1.281	.460	.119	.058	.077	.022	4.797
ATMOS NITROGEN OXIDES	POUND	7.673	1.888	.828	.683	.207	1.007	1.478	.229	13.992
ATMOS HYDROCARBONS	POUND	21.408	.735	1.074	.316	.080	.447	.561	.232	24.855
ATMOS SULFUR OXIDES	POUND	7.707	4.796	2.111	1.564	.525	.174	.245	.056	17.179
ATMOS CARBON MONOXIDE	POUND	1.595	.234	.234	.139	.026	2.300	1.864	2.213	8.604
ATMOS ALDEHYDES	POUND	.012	.003	.003	.001	.000	.029	.027	.018	.094
ATMOS OTHER ORGANICS	POUND	.024	.004	.244	.003	.000	.086	.068	.192	.622
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	.009	0.000	0.000	0.000	0.000	.009
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	0.000	.001	.002	.001	.004
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	.000	0.000	.005	.004	.004	.014
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	.014	0.000	0.000	0.000	0.000	.014
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	2.297	.103	.250	.144	.011	.278	.304	.114	3.501
WATERBORNE BOD	POUND	.106	.000	.620	.101	.203	.001	.001	.000	1.032
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.026	.000	.001	.000	.000	.000	.000	.000	.028
WATERBORNE COD	POUND	.768	.001	.031	.000	.000	.003	.003	.001	.808
WATERBORNE SUSP SOLIDS	POUND	.249	.001	.296	.179	.304	.002	.002	.001	1.033
WATERBORNE ACID	POUND	.372	.268	.035	.089	.029	.001	.001	.000	.796
WATERBORNE METAL ION	POUND	.093	.067	.009	.021	.007	.000	.000	.000	.197
WATERBORNE CHEMICALS	POUND	0.000	0.000	.023	0.000	0.000	0.000	0.000	0.000	.023
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	.000	0.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
NAME	UNITS									
RAW MATERIALS	POUNDS	24.144	0.000	23.438	20.359	0.000	0.000	0.000	0.000	67.941
ENERGY	MIL BTU	17.141	1.791	1.155	.989	.196	.547	.635	.214	22.668
WATER	THOU GAL	.789	.915	.067	.261	.003	.032	.035	.013	2.115
INDUSTRIAL SOLID WASTES	CUBIC FT	.497	.372	.089	.140	.035	.002	.002	.001	1.138
ATM EMMISSIONS	POUNDS	40.113	8.747	5.776	3.190	.958	4.108	4.325	2.968	70.185
WATERBORNE WASTES	POUNDS	3.911	.440	1.265	.535	.555	.285	.311	.117	7.419
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	79.564	79.564
ENERGY SOURCE PETROLEUM	MIL BTU	2.768	.359	.248	.237	.039	.547	.592	.214	5.005
ENERGY SOURCE NAT GAS	MIL BTU	12.887	.363	.557	.167	.040	0.000	.043	0.000	14.056
ENERGY SOURCE COAL	MIL BTU	1.212	.872	.157	.312	.095	0.000	0.000	0.000	2.650
ENERGY SOURCE NUCL HYPWR	MIL BTU	.274	.197	.017	.054	.022	0.000	0.000	0.000	.563
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.176	.219	0.000	0.000	0.000	0.000	.394
INDEX OF ENVIRONMENTAL IMPACTS										
NAME	STANDARD VALUES									
RAW MATERIALS	67.941	35.5	0.0	34.5	30.0	0.0	0.0	0.0	0.0	100.0
ENERGY	22.668	75.6	7.9	5.1	4.4	.9	2.4	2.8	.9	100.0
WATER	2.115	37.3	43.2	3.2	12.3	.1	1.5	1.7	.6	100.0
INDUSTRIAL SOLID WASTES	1.138	43.7	32.7	7.9	12.3	3.1	.2	.2	.1	100.0
ATM EMMISSIONS	70.185	57.2	12.5	8.2	4.5	1.4	5.9	6.2	4.2	100.0
WATERBORNE WASTES	7.419	52.7	5.9	17.1	7.2	7.5	3.8	4.2	1.6	100.0
POST-CONSUMER SOL WASTE	79.564	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	5.005	55.3	7.2	5.0	4.7	.8	10.9	11.8	4.3	100.0
ENERGY SOURCE NAT GAS	14.056	91.7	2.6	4.0	1.2	.3	0.0	.3	0.0	100.0
ENERGY SOURCE COAL	2.650	45.7	32.9	5.9	11.8	3.6	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.563	48.7	35.0	3.0	9.5	3.8	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.394	0.0	0.0	44.6	55.4	0.0	0.0	0.0	0.0	100.0

TABLE 27

SUMMARY OF IMPACTS FOR 1,000 GALLONS OF MILK IN EACH NONREFILLABLE PLASTIC SYSTEM

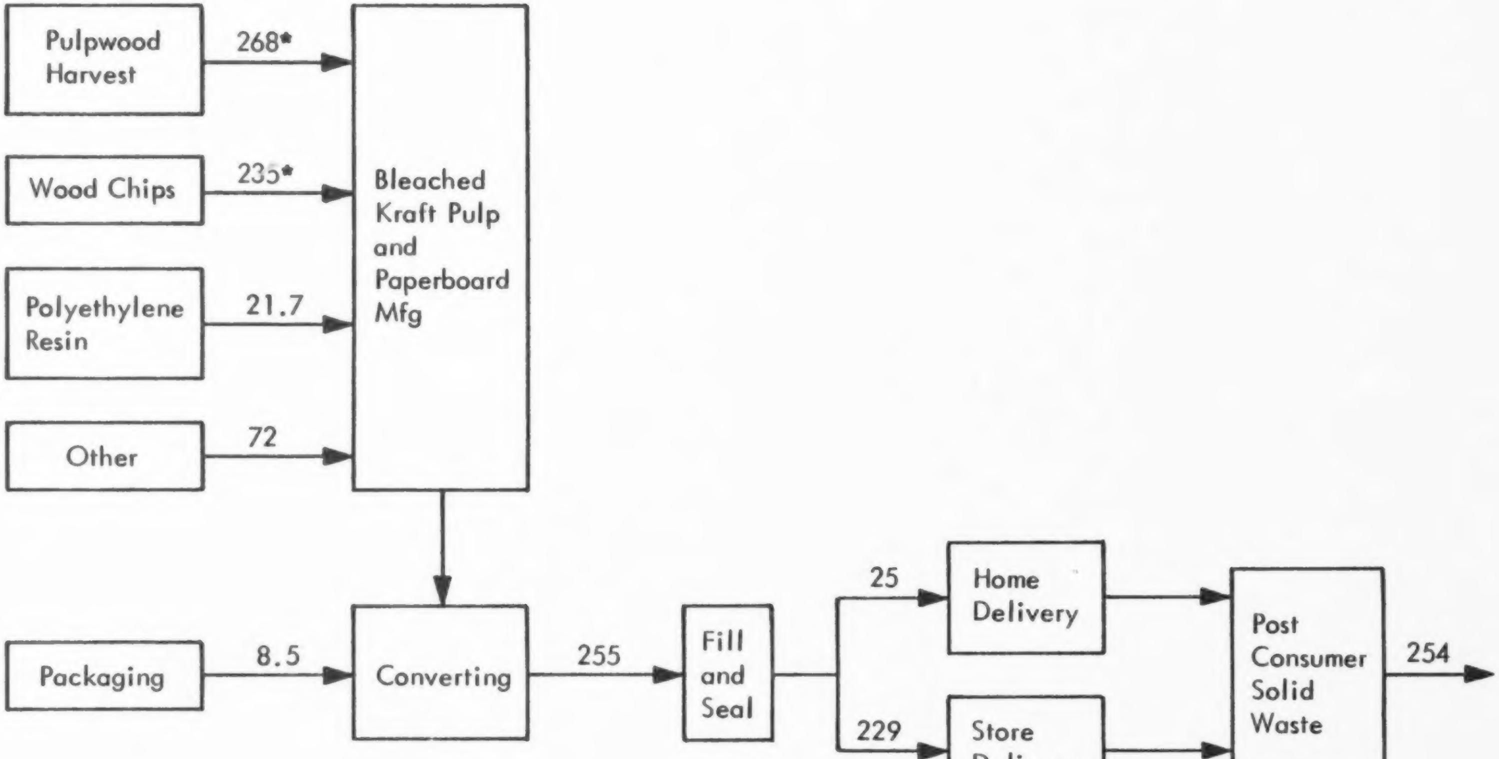
Impact category	Impacts Gallon	 Half gallon	 Half pint
Raw materials, lb	17.70	20.45	67.94
Energy, 10^6 Btu	8.78	10.13	22.67
Water, 10^3 gallons	0.66	0.72	2.12
Industrial solid waste, ft^3	0.38	0.44	1.14
Atmospheric emissions, lb	30.86	34.78	70.18
Waterborne wastes, lb	3.13	3.50	7.42
Postconsumer solid waste, ft^3	75.43	75.80	79.56
Energy source petroleum, 10^6 Btu	2.43	2.69	5.00
Energy source natural gas, 10^6 Btu	5.23	6.12	14.06
Energy source coal, 10^6 Btu	0.87	1.03	2.65
Energy source misc., 10^6 Btu	0.19	0.22	0.56
Energy source wood waste, 10^6 Btu	0.06	0.07	0.39

Source: Midwest Research Institute.

E. Nonrefillable Paperboard Cartons

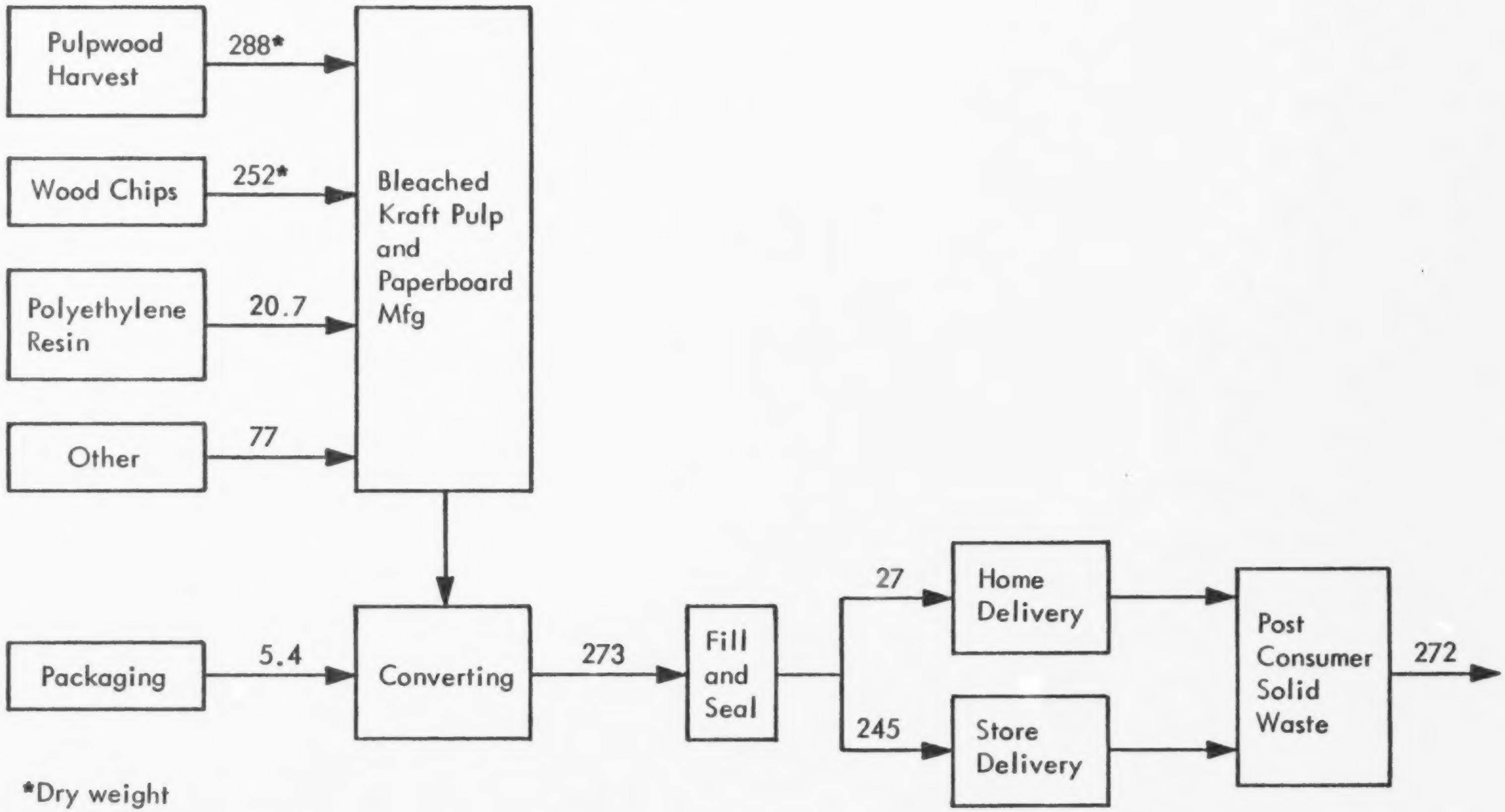
1. Overview: The paperboard milk cartons analyzed in this study are bleached kraft paperboard which has been coated with low density polyethylene. Bleached paperboard is manufactured from wood fiber and is coated with polyethylene in a converting operation in which the coated paperboard is cut into carton blanks. The carton blanks are shipped to dairies, where filling equipment sets up the blank and seals the bottom by applying heat and pressure. The carton is then filled with milk, and the gable top is formed and sealed in a similar fashion; the containers are then delivered for final sale or consumption. The flow diagrams showing the material requirements for the three paperboard systems are presented in Figures 20, 21, and 22.

2. Profile analysis: The impacts associated with the manufacture and use of paperboard cartons which deliver 1,000 gallons of milk in one gallon paperboard containers are given in Table 28.


Pulpwood Harvest
268*
Wood Chips
235*
Polyethylene Resin
21.7
Other
72
Bleached Kraft Pulp and Paperboard Mfg
Packaging
8.5
Converting
255
Fill and Seal
25
229
Home Delivery
Store Delivery
Post Consumer Solid Waste
254

*Dry weight

Figure 20. Flow diagram shows delivery of 1,000 gallons of milk in refillable paperboard gallon cartons (in pounds).


Pulpwood Harvest
288*
Wood Chips
252*
Polyethylene Resin
20.7
Other
77
Bleached Kraft Pulp and Paperboard Mfg
Packaging
5.4
Converting
273
Fill and Seal
27
245
Home Delivery
Store Delivery
Post Consumer Solid Waste
272

*Dry weight

Figure 21. Flow diagram shows delivery of 1,000 gallons of milk in nonrefillable paperboard half gallon cartons (in pounds).

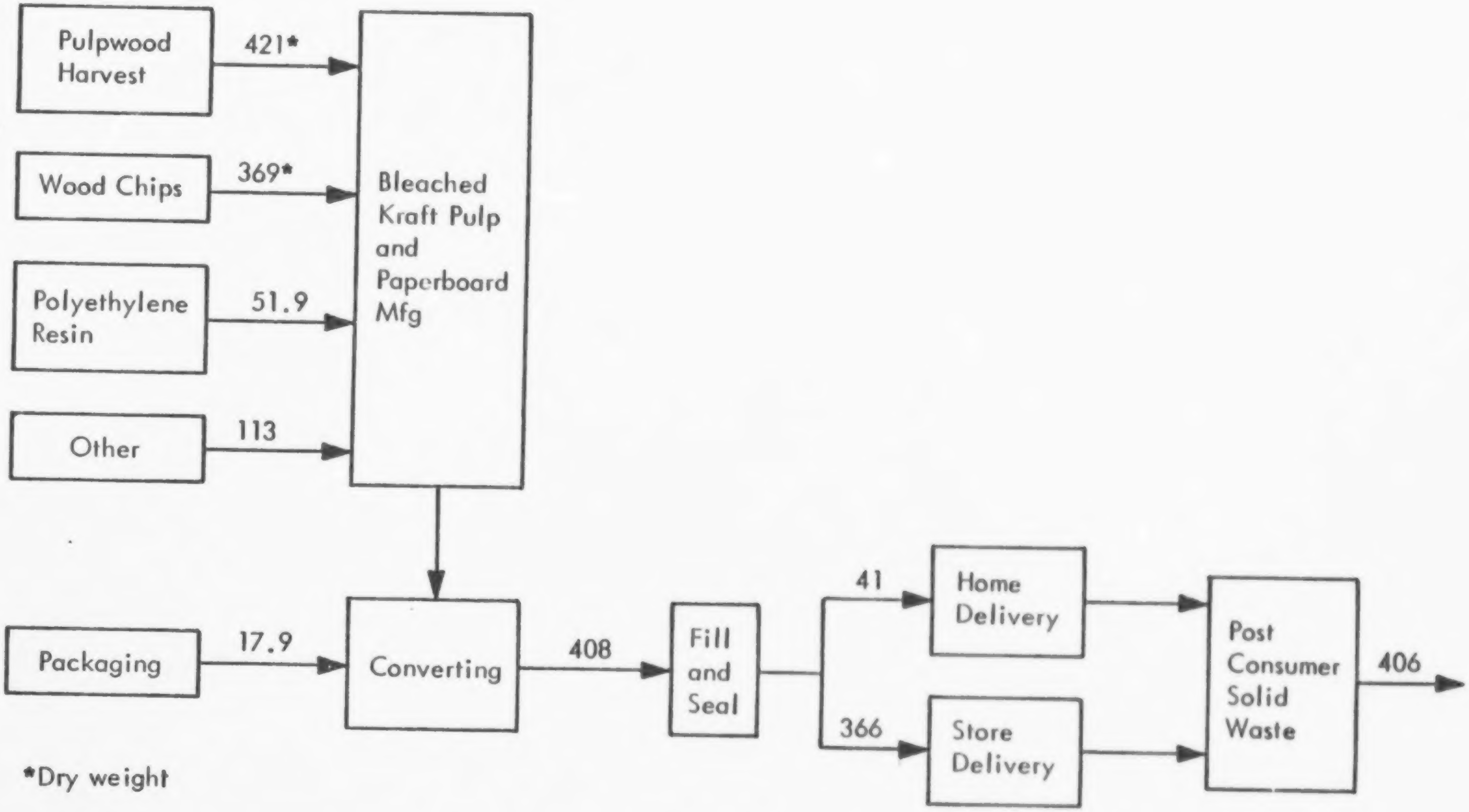

Pulpwood Harvest
421*
Wood Chips
369*
Polyethylene Resin
51.9
Other
113
Bleached Kraft Pulp and Paperboard Mfg
Packaging
17.9
Converting
408
Fill and Seal
41
366
Home Delivery
Store Delivery
Post Consumer Solid Waste
406
*Dry weight

Figure 22. Flow diagram shows delivery of 1,000 gallons of milk in nonrefillable paperboard half pint cartons (in pounds).

TABLE 28

IMPACTS FOR 1,000 GALLONS OF MILK DELIVERED IN THE NONREFILLABLE PAPERBOARD ONE GALLON CONTAINER SYSTEM

		BLEACHED KRAFT SYSTEM 249 LB	PLASTIC RESIN SYSTEM 21.7 LB	CONVERT GALLON CONT 255 LB	FILL AND SEAL GAL CONT	CORRUG PKG SYS 8.5 LB	PAPERBD GAL SYS TRANS	MILK DELIVERY	POST CON SOLID WASTE 271 LB	SYSTEM TOTALS
INPUTS TO SYSTEMS										
NAME	UNITS									
MATERIAL WOOD FIBER	POUNDS	131.970	0.000	0.000	0.000	5.926	0.000	0.000	0.000	137.896
MATERIAL LIMESTONE	POUND	39.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	39.840
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	29.755	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29.755
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	1.687	.147	.008	.022	.039	.220	.738	.081	2.942
ENERGY SOURCE NAT GAS	MILL BTU	.915	.664	.038	.065	.025	.002	0.000	0.000	1.708
ENERGY SOURCE COAL	MILL BTU	1.240	.079	.018	.052	.024	0.000	0.000	0.000	1.413
ENERGY SOURCE MISC	MILL BTU	.094	.018	.004	.012	0.000	0.000	0.000	0.000	.128
ENERGY SOURCE WOOD FIBER	MILL BTU	2.373	0.000	0.000	0.000	.050	0.000	0.000	0.000	2.423
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	19.515	.565	10.710	0.000	.595	0.000	0.000	0.000	31.385
ENERGY PROCESS	MIL BTU	6.237	.376	.068	.151	.136	0.000	0.000	0.000	6.968
ENERGY TRANSPORT	MIL BTU	.072	.011	.001	0.000	.001	.222	.738	.081	1.126
ENERGY OF MATL RESOURCE	MIL BTU	.010	.521	0.000	0.000	0.000	0.000	0.000	0.000	.531
WATER VOLUME	THOU GAL	2.760	.043	.001	.002	.003	.013	.044	.005	2.872
OUTPUTS FROM SYSTEMS										
NAME	UNITS									
SOLID WASTES PROCESS	POUND	34.960	.517	.255	.430	.560	0.000	0.000	0.000	36.732
SOLID WASTES FUEL COMB	POUND	14.401	.464	.108	.307	.306	.051	.179	.025	15.916
SOLID WASTES MINING	POUND	7.201	1.264	.296	.836	.336	0.000	0.000	0.000	10.011
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30.386	30.386
ATMOS PARTICULATES	POUND	2.311	.121	.024	.066	.332	.032	.078	.008	2.972
ATMOS NITROGEN OXIDES	POUND	2.795	.429	.056	.136	.130	.508	1.169	.086	5.278
ATMOS HYDROCARBONS	POUND	1.619	1.196	.045	.085	.083	.106	.670	.080	3.876
ATMOS SULFUR OXIDES	POUND	5.167	.487	.101	.287	.472	.104	.220	.021	6.860
ATMOS CARBON MONOXIDE	POUND	.934	.086	.012	.019	.048	.483	3.840	.988	6.411
ATMOS ALDEHYDES	POUND	.008	.001	.000	.000	.001	.009	.047	.007	.072
ATMOS OTHER ORGANICS	POUND	.023	.001	.000	.000	.069	.018	.153	.101	.367
ATMOS ODOROUS SULFUR	POUND	.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.100
ATMOS AMMONIA	POUND	.000	.000	.000	0.000	.000	.001	.002	.000	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.001	.000	.000	0.000	.000	.001	.010	.002	.014
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	.168	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.168
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	1.307	.119	.008	.014	.047	.109	.382	.043	2.028
WATERBORNE BOD	POUND	1.097	.006	.000	.160	.174	.000	.001	.000	1.439
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.000	.001	.000	.000	.000	.000	.000	.000	.002
WATERBORNE COD	POUND	.001	.044	.000	.000	.000	.001	.004	.000	.051
WATERBORNE SUSP SOLIDS	POUND	1.907	.014	.000	.240	.081	.001	.002	.000	2.246
WATERBORNE ACID	POUND	.305	.024	.006	.016	.004	.000	.001	.000	.355
WATERBORNE METAL ION	POUND	.062	.006	.001	.004	.001	.000	.000	.000	.076
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	.006	0.000	0.000	0.000	.006
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
NAME	UNITS									
RAW MATERIALS	POUNDS	221.081	.565	10.710	0.000	6.519	0.000	0.000	0.000	238.875
ENERGY	MIL BTU	6.319	.907	.069	.151	.137	.222	.738	.081	8.624
WATER	THOU GAL	2.760	.043	.001	.002	.003	.013	.044	.005	2.872
INDUSTRIAL SOLID WASTES	CUBIC FT	.765	.030	.009	.021	.017	.001	.002	.000	.866
ATM EMMISSIONS	POUNDS	13.048	2.225	.239	.594	1.142	1.338	6.190	1.302	26.078
WATERBORNE WASTES	POUNDS	4.720	.214	.015	.436	.313	.112	.391	.044	6.243
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30.386	30.386
ENERGY SOURCE PETROLEUM	MIL BTU	1.687	.147	.008	.022	.039	.220	.738	.081	2.942
ENERGY SOURCE NAT GAS	MIL BTU	.915	.664	.038	.065	.025	.002	0.000	0.000	1.708
ENERGY SOURCE COAL	MIL BTU	1.240	.079	.018	.052	.024	0.000	0.000	0.000	1.413
ENERGY SOURCE NUCL HYPWR	MIL BTU	.094	.018	.004	.012	0.000	0.000	0.000	0.000	.128
ENERGY SOURCE WOOD WASTE	MIL BTU	2.373	0.000	0.000	0.000	.050	0.000	0.000	0.000	2.423
INDEX OF ENVIRONMENTAL IMPACTS										
NAME	STANDARD VALUES									
RAW MATERIALS	238.875	92.6	.2	4.5	0.0	2.7	0.0	0.0	0.0	100.0
ENERGY	8.624	73.3	10.5	.8	1.7	1.6	2.6	8.6	.9	100.0
WATER	2.872	96.1	1.5	.0	.1	.1	.4	1.5	.2	100.0
INDUSTRIAL SOLID WASTES	.866	90.4	3.6	1.0	2.5	2.1	.1	.3	.0	100.0
ATM EMMISSIONS	26.078	50.0	8.5	.9	2.3	4.4	5.1	23.7	5.0	100.0
WATERBORNE WASTES	6.243	75.6	3.4	.2	7.0	5.0	1.8	6.3	.7	100.0
POST-CONSUMER SOL WASTE	30.386	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	2.942	57.3	5.0	.3	.7	1.3	7.5	25.1	2.8	100.0
ENERGY SOURCE NAT GAS	1.708	53.6	38.8	2.2	3.8	1.4	.1	0.0	0.0	100.0
ENERGY SOURCE COAL	1.413	87.8	5.6	1.3	3.7	1.7	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.128	73.6	13.9	3.2	9.2	0.0	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	2.423	97.9	0.0	0.0	0.0	2.1	0.0	0.0	0.0	100.0

Eight processes or steps are identified; however, one process dominates the impact profile--the bleached draft system. It accounts for more than 50 percent of the total impacts in every impact category (except postconsumer solid waste). The dominance ranges from 96 percent of the water required for all systems to 50 percent of the atmospheric pollutants released by all systems. This process requires 73 percent of the total system energy. The remaining impacts are distributed over the other seven processes, although the LDPE coating system requires 10.5 percent of the total system energy, which makes that process the second largest energy consumer of the eight processes.

The energy requirement for pulp and paperboard manufacture includes 2.37 million Btu derived from wood wastes and 3.84 million Btu derived from fossil fuels. Thus, wood wastes account for 37.5 percent of the energy required for this process.

There are two sources for wood waste energy. Pulp and paperboard mills utilize bark and other "wasted" wood components accompanying trees into a wood processing complex. These wood components are broken into small sizes by milling (hogging) and then are burned in a "hog fuel" boiler designed to handle that type of fuel. This accounts for about 12 percent of the wood waste derived energy.

Second, wood components are also removed from the usable fiber during the kraft digestion process in the manufacture of the pulp. These wood components are contained in the "black liquor," which is burned in a special recovery boiler designed for the recovery of chemicals and energy from black liquor. This black liquor is a product of the digestion process, and the recovery of chemicals and heat is an integral and important part of the kraft pulping process. Black liquor is not a source of energy that is available to the general public or to other industries for that matter. Thus, the energy recovered from these wood residues is clearly from a different type of source than fossil fuels. For this reason it has been treated as a distinctly separate category in the energy analysis and has not been added to the total energy derived from fossil fuels.

In addition to unique energy use patterns in papermaking, the raw material utilization pattern of mills manufacturing milk container paperboard show some other important characteristics. Although 316 pounds of wood fiber are required to make the paperboard cartons summarized in Table 28, only 167 pounds of fiber are derived directly from trees harvested for the purpose of making paper. The remaining 149 pounds of fiber are derived from wood residues, primarily from other wood processing industries. These residues are mostly sawdust, chips, and other wasted wood from sawmills, plywood mills, etc. Only a few years ago these residues were burned with no energy recovery, so the use of these materials in paperboard manufacture represents utilization of what was formerly an industrial waste material.

TABLE 29

IMPACTS FOR 1,000 GALLONS OF MILK DELIVERED IN THE NONREFILLABLE PAPERBOARD HALF GALLON CONTAINER SYSTEM

INPUTS TO SYSTEMS

NAME	UNITS	BLEACHED KRAFT SYSTEM 267 LB	PLASTIC RESIN SYSTEM 20.7 LB	CONVERT HALF GAL CONT 273 LB	FILL AND SEAL HG CONT	CORRUG PKG SYS 5.4 LB	PAPERBD HALF GAL SYS TRAN	MILK DELIVERY	POST CON SOLID WASTE 272 LB	SYSTEM TOTALS
MATERIAL WOOD FIBER	POUNDS	141.510	0.000	0.000	0.000	3.764	0.000	0.000	0.000	145.274
MATERIAL LIMESTONE	POUND	42.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	42.720
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	31.906	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31.906
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	1.809	.140	.009	.026	.025	.233	.738	.083	3.061
ENERGY SOURCE NAT GAS	MILL BTU	.981	.633	.041	.084	.016	.002	0.000	0.000	1.756
ENERGY SOURCE COAL	MILL BTU	1.329	.075	.020	.057	.015	0.000	0.000	0.000	1.497
ENERGY SOURCE MISC	MILL BTU	.101	.017	.004	.013	0.000	0.000	0.000	0.000	.136
ENERGY SOURCE WOOD FIBER	MILL BTU	2.545	0.000	0.000	0.000	.032	0.000	0.000	0.000	2.576
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	20.926	.539	7.371	0.000	.378	0.000	0.000	0.000	29.214
ENERGY PROCESS	MIL BTU	6.688	.356	.073	.178	.086	0.000	0.000	0.000	7.384
ENERGY TRANSPORT	MIL BTU	.077	.010	.001	0.000	.000	.235	.738	.083	1.164
ENERGY OF MATL RESOURCE	MIL BTU	.011	.497	0.000	0.000	0.000	0.000	0.000	0.000	.507
WATER VOLUME	THOU GAL	2.960	.041	.001	.003	.002	.013	.044	.005	3.070

OUTPUTS FROM SYSTEMS

NAME	UNITS	BLEACHED KRAFT SYSTEM 267 LB	PLASTIC RESIN SYSTEM 20.7 LB	CONVERT HALF GAL CONT 273 LB	FILL AND SEAL HG CONT	CORRUG PKG SYS 5.4 LB	PAPERBD HALF GAL SYS TRAN	MILK DELIVERY	POST CON SOLID WASTE 272 LB	SYSTEM TOTALS
SOLID WASTES PROCESS	POUND	37.480	.493	.273	.430	.342	0.000	0.000	0.000	39.044
SOLID WASTES FUEL COMB	POUND	15.442	.443	.116	.338	.245	.054	.170	.021	16.837
SOLID WASTES MINING	POUND	7.808	1.206	.319	.920	.213	0.000	0.000	0.000	10.441
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30.984	30.984
ATMOS PARTICULATES	POUND	2.478	.116	.025	.073	.211	.033	.078	.009	3.023
ATMOS NITROGEN OXIDES	POUND	2.955	.409	.060	.156	.088	.537	1.169	.388	5.462
ATMOS HYDROCARBONS	POUND	1.736	1.349	.048	.105	.053	.194	.670	.390	3.965
ATMOS SULFUR OXIDES	POUND	5.519	.464	.109	.316	.300	.111	.220	.021	7.040
ATMOS CARBON MONOXIDE	POUND	1.002	.082	.013	.022	.330	.511	3.840	1.008	6.509
ATMOS ALDEHYDES	POUND	.008	.001	.000	.000	.000	.009	.047	.007	.073
ATMOS OTHER ORGANICS	POUND	.025	.001	.000	.001	.044	.019	.153	.103	.347
ATMOS ODOROUS SULFUR	POUND	.107	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.107
ATMOS AMMONIA	POUND	.000	.000	.000	0.000	.000	.001	.002	.000	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.002	.000	.000	0.000	.000	.001	.010	.002	.016
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	.159	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.159
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	1.401	.114	.008	.017	.030	.114	.382	.044	2.111
WATERBORNE BOD	POUND	1.177	.006	.000	.160	.111	.000	.001	.000	1.454
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.000	.001	.000	.000	.000	.000	.000	.000	.002
WATERBORNE COD	POUND	.001	.042	.000	.000	.000	.001	.004	.000	.049
WATERBORNE SUSP SOLIDS	POUND	2.088	.013	.000	.240	.051	.001	.002	.000	2.396
WATERBORNE ACID	POUND	.327	.023	.006	.018	.002	.000	.001	.000	.377
WATERBORNE METAL ION	POUND	.067	.006	.002	.004	.001	.000	.000	.000	.079
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	.004	0.000	0.000	0.000	.004
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

SUMMARY OF ENVIRONMENTAL IMPACTS

NAME	UNITS	BLEACHED KRAFT SYSTEM 267 LB	PLASTIC RESIN SYSTEM 20.7 LB	CONVERT HALF GAL CONT 273 LB	FILL AND SEAL HG CONT	CORRUG PKG SYS 5.4 LB	PAPERBD HALF GAL SYS TRAN	MILK DELIVERY	POST CON SOLID WASTE 272 LB	SYSTEM TOTALS
RAW MATERIALS	POUNDS	237.062	.539	7.371	0.000	4.142	0.000	0.000	0.000	249.114
ENERGY	MIL BTU	6.776	.865	.073	.178	.087	.235	.738	.083	9.036
WATER	THOU GAL	2.960	.041	.001	.003	.002	.013	.044	.005	3.070
INDUSTRIAL SOLID WASTES	CUBIC FT	.820	.029	.010	.023	.011	.001	.002	.000	.896
ATM EMMISSIONS	POUNDS	13.992	2.122	.256	.673	.725	1.417	6.190	1.328	26.702
WATERBORNE WASTES	POUNDS	5.061	.205	.016	.439	.199	.119	.391	.045	6.475
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30.984	30.984
ENERGY SOURCE PETROLEUM	MIL BTU	1.809	.140	.009	.024	.025	.233	.738	.083	3.061
ENERGY SOURCE NAT GAS	MIL BTU	.981	.633	.041	.084	.016	.002	0.000	0.000	1.756
ENERGY SOURCE COAL	MIL BTU	1.329	.075	.020	.057	.015	0.000	0.000	0.000	1.497
ENERGY SOURCE NUCL HYPWR	MIL BTU	.101	.017	.004	.013	0.000	0.000	0.000	0.000	.136
ENERGY SOURCE WOOD WASTE	MIL BTU	2.545	0.000	0.000	0.000	.032	0.000	0.000	0.000	2.576

INDEX OF ENVIRONMENTAL IMPACTS

NAME	STANDARD VALUES	BLEACHED KRAFT SYSTEM 267 LB	PLASTIC RESIN SYSTEM 20.7 LB	CONVERT HALF GAL CONT 273 LB	FILL AND SEAL HG CONT	CORRUG PKG SYS 5.4 LB	PAPERBD HALF GAL SYS TRAN	MILK DELIVERY	POST CON SOLID WASTE 272 LB	SYSTEM TOTALS
RAW MATERIALS	249.114	95.2	.2	3.0	0.0	1.7	0.0	0.0	0.0	100.0
ENERGY	9.036	75.0	9.6	.8	2.0	1.0	2.6	8.2	.9	100.0
WATER	3.070	96.4	1.3	.0	.1	.1	.4	1.4	.2	100.0
INDUSTRIAL SOLID WASTES	.896	91.5	3.2	1.1	2.5	1.2	.1	.3	.0	100.0
ATM EMMISSIONS	26.702	52.4	7.9	1.0	2.5	2.7	5.3	23.2	5.0	100.0
WATERBORNE WASTES	6.475	78.2	3.2	.2	6.8	3.1	1.8	6.0	.7	100.0
POST-CONSUMER SOL WASTE	30.984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	3.061	59.1	4.6	.3	.8	.8	7.6	24.1	2.7	100.0
ENERGY SOURCE NAT GAS	1.756	55.9	36.0	2.3	4.8	.9	.1	0.0	0.0	100.0
ENERGY SOURCE COAL	1.497	88.8	5.0	1.3	3.8	1.0	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.136	74.6	12.5	3.3	9.6	0.0	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	2.576	98.8	0.0	0.0	0.0	1.2	0.0	0.0	0.0	100.0

3. Different sizes of containers: A summary of the impacts for the manufacture of containers delivering 1,000 gallons of milk in half gallon and half pint containers is given in Tables 29 and 30. The same statements made for the gallon containers above hold approximately true for the half gallon and half pint systems. However, because more material is required per 1,000 gallons of milk for half gallons and half pints, the numbers are all larger. But, in each case the bleached kraft pulp and paperboard manufacturing process dominates the profile. Thus, larger volume packaging is more environmentally efficient in this case than smaller volume packaging. Significant design improvements also have been made in the paperboard carton recently. For example, one new design in use for one half pint cartons utilizes 15 percent less fiber than the conventional gable-top container. The impacts of this type container are only partly reflected in the data in this study, but the market penetration of the new design is expected to move forward rapidly in the next few years.

F. Nonrefillable Plastic Pouch Systems

1. Overview: The flow diagrams showing the material requirements for the gallon, half gallon and half pint plastic pouch systems are given in Figures 23, 24, and 25. The crude oil and natural gas raw materials are processed and converted into ethylene. Ethylene is the monomer for the low density polyethylene resin used to manufacture the plastic film which is later formed into the plastic pouch milk container. The outer bag used to package one gallon of milk in the pouch gallon system is also made from low density polyethylene. The plastic pitcher used to serve milk from the gallon and half gallon systems were assumed to be constructed of high density polyethylene. The straws used with the half pint systems were assigned the impacts associated with producing a low density polyethylene bag.

2. Profile analysis: The impact data for 1,000 gallons of the nonrefillable plastic pouch gallon system are presented in Table 31. The system contains eight separate processes. The low density polyethylene resin subsystem has the highest impacts for the raw materials and energy categories. The subsystem contains the pitcher and outer plastic bag leads in the water and solid waste categories. The pouch fill-and-seal operation accounts for the highest impacts in waterborne wastes, composed primarily of BOD and suspended solids associated with the 0.5 percent loss estimated for the filling operation.

Table 32 lists the seven impact categories along with the processes which show the greatest impact within each category. The outer bag process has about the same impacts as the resin system since the weight of the bag is 45 percent of the weight of the entire gallon pouch container (two half gallon pouches packaged in one outer plastic bag).

TABLE 30

IMPACTS FOR 1,000 GALLONS OF MILK DELIVERED IN THE NON-REFILLABLE PAPERBOARD HALF PINT CONTAINER SYSTEM

NAME	UNITS	BLEACHED KRAFT SYSTEM 391 LB	PLASTIC RESIN SYSTEM 51.9 LB	CONVERT HALF PT CONT 408 LB	FILL AND SEAL HPT CONT	CORRUG PKG SYS 17.9 LB	PAPERBD HALF PT SYS TRAN	MILK DELIVERY	POST CON SOLID WASTE 406 LB	SYSTEM TOTALS
INPUTS TO SYSTEMS										
MATERIAL WOOD FIBER	POUNDS	207.230	0.000	0.000	0.000	12.476	0.000	0.000	0.000	219.706
MATERIAL LIMESTONE	POUND	62.560	0.000	0.000	0.000	0.000	0.000	0.000	0.000	62.560
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	46.724	0.000	0.000	0.000	0.000	0.000	0.000	0.000	46.724
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	2.650	.351	.013	.073	.082	.359	.547	.071	4.145
ENERGY SOURCE NAT GAS	MILL BTU	1.437	1.587	.061	.076	.052	.005	0.000	0.000	3.215
ENERGY SOURCE COAL	MILL BTU	1.947	.189	.029	.177	.050	0.000	0.000	0.000	2.392
ENERGY SOURCE MISC	MILL BTU	.148	.043	.007	.040	0.000	0.000	0.000	0.000	.238
ENERGY SOURCE WOOD FIBER	MILL BTU	3.726	0.000	0.000	0.000	.105	0.000	0.000	0.000	3.831
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	30.644	1.350	22.032	0.000	1.253	0.000	0.000	0.000	55.280
ENERGY PROCESS	MIL BTU	9.794	.899	.109	.364	.287	0.000	0.000	0.000	11.453
ENERGY TRANSPORT	MIL BTU	.113	.026	.001	0.000	.002	.364	.547	.071	1.123
ENERGY OF MATL RESOURCE	MIL BTU	.016	1.245	0.000	0.000	0.000	0.000	0.000	0.000	1.261
WATER VOLUME	THOU GAL	4.334	.103	.002	.006	.006	.021	.032	.004	4.508
OUTPUTS FROM SYSTEMS										
SOLID WASTES PROCESS	POUND	54.897	1.237	.408	.430	1.199	0.000	0.000	0.000	58.171
SOLID WASTES FUEL COMB	POUND	22.614	1.110	.173	1.044	.812	.083	.130	.018	25.984
SOLID WASTES MINING	POUND	11.433	3.023	.471	2.842	.707	0.000	0.000	0.000	18.477
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	35.529	35.529
ATMOS PARTICULATES	POUND	3.629	.290	.038	.221	.699	.051	.058	.007	4.994
ATMOS NITROGEN OXIDES	POUND	4.327	1.026	.090	.384	.290	.837	1.007	.075	8.036
ATMOS HYDROCARBONS	POUND	2.543	2.631	.072	.150	.175	.302	.447	.077	6.395
ATMOS SULFUR OXIDES	POUND	8.083	1.164	.162	.976	.993	.170	.174	.018	11.740
ATMOS CARBON MONOXIDE	POUND	1.467	.206	.020	.048	.101	.788	2.300	1.157	6.086
ATMOS ALDEHYDES	POUND	.012	.002	.000	.001	.001	.015	.028	.006	.065
ATMOS OTHER ORGANICS	POUND	.037	.003	.001	.001	.145	.029	.086	.143	.444
ATMOS ODOROUS SULFUR	POUND	.156	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.156
ATMOS AMMONIA	POUND	.000	.000	.000	0.000	.000	.001	.001	.000	.003
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.002	.000	.000	0.000	.000	.001	.005	.001	.010
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	.233	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.233
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	2.052	.205	.012	.021	.098	.178	.278	.038	2.882
WATERBORNE BOD	POUND	1.723	.014	.000	.160	.367	.000	.001	.000	2.265
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.000	.003	.000	.000	.000	.000	.000	.000	.004
WATERBORNE COD	POUND	.001	.105	.000	.000	.000	.002	.003	.000	.112
WATERBORNE SUSP SOLIDS	POUND	3.058	.034	.000	.240	.170	.001	.002	.000	3.505
WATERBORNE ACID	POUND	.479	.058	.009	.054	.008	.000	.001	.000	.608
WATERBORNE METAL ION	POUND	.098	.014	.002	.014	.002	.000	.000	.000	.130
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	.014	0.000	0.000	0.000	.014
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE LEAD	POUND	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
RAW MATERIALS	POUNDS	347.159	1.350	22.032	0.000	13.729	0.000	0.000	0.000	384.270
ENERGY	MIL BTU	9.923	2.170	.110	.364	.288	.364	.547	.071	13.837
WATER	THOU GAL	4.334	.103	.002	.006	.006	.021	.032	.004	4.508
INDUSTRIAL SOLID WASTES	CUBIC FT	1.201	.072	.014	.058	.037	.001	.002	.000	1.386
ATM EMMISSIONS	POUNDS	20.490	5.321	.382	1.780	2.404	2.194	4.108	1.486	38.165
WATERBORNE WASTES	POUNDS	7.411	.513	.024	.490	.659	.183	.285	.039	9.603
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	35.529	35.529
ENERGY SOURCE PETROLEUM	MIL BTU	2.650	.351	.013	.073	.082	.359	.547	.071	4.145
ENERGY SOURCE NAT GAS	MIL BTU	1.437	1.587	.061	.074	.052	.005	0.000	0.000	3.215
ENERGY SOURCE COAL	MIL BTU	1.947	.189	.029	.177	.050	0.000	0.000	0.000	2.392
ENERGY SOURCE NUCL HYPWR	MIL BTU	.148	.043	.007	.040	0.000	0.000	0.000	0.000	.238
ENERGY SOURCE WOOD WASTE	MIL BTU	3.726	0.000	0.000	0.000	.105	0.000	0.000	0.000	3.831
INDEX OF ENVIRONMENTAL IMPACTS	STANDARD VALUES									
RAW MATERIALS	384.270	90.3	.4	5.7	0.0	3.6	0.0	0.0	0.0	100.0
ENERGY	13.837	71.7	15.7	.8	2.6	2.1	2.6	4.0	.5	100.0
WATER	4.508	96.1	2.3	.0	.1	.1	.5	.7	.1	100.0
INDUSTRIAL SOLID WASTES	1.386	86.7	5.2	1.0	4.2	2.6	.1	.1	.0	100.0
ATM EMMISSIONS	38.165	53.7	13.9	1.0	4.7	6.3	5.7	10.8	3.9	100.0
WATERBORNE WASTES	9.603	77.2	5.3	.2	5.1	6.9	1.9	3.0	.4	100.0
POST-CONSUMER SOL WASTE	35.529	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	4.145	63.9	8.5	.3	1.8	2.0	8.7	13.2	1.7	100.0
ENERGY SOURCE NAT GAS	3.215	44.7	49.4	1.9	2.3	1.6	.1	0.0	0.0	100.0
ENERGY SOURCE COAL	2.392	81.4	7.9	1.2	7.4	2.1	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.238	62.4	17.9	2.8	16.9	0.0	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	3.831	97.3	0.0	0.0	0.0	2.7	0.0	0.0	0.0	100.0

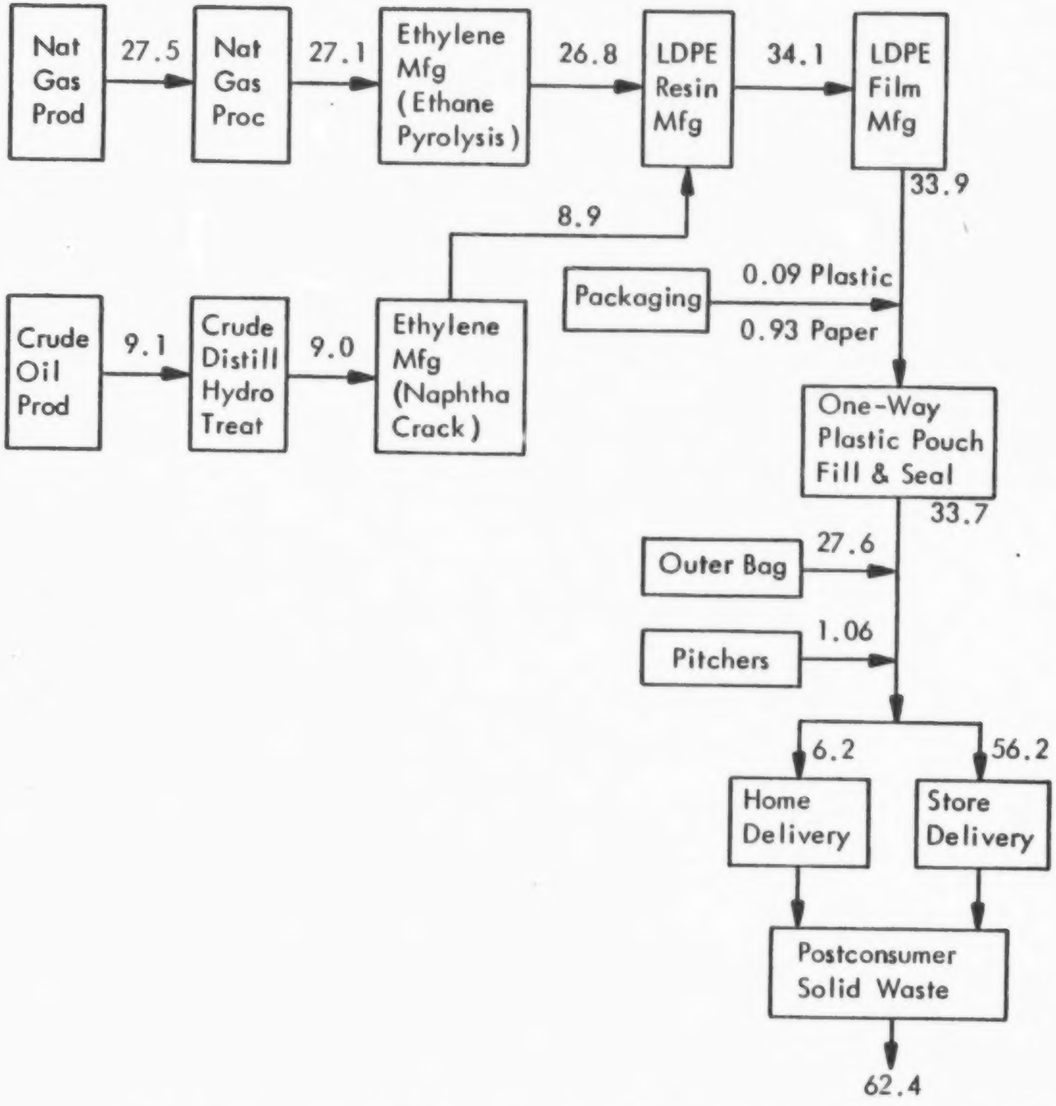

Nat Gas Prod
27.5
Nat Gas Proc
27.1
Ethylene Mfg (Ethane Pyrolysis)
26.8
LDPE Resin Mfg
34.1
LDPE Film Mfg
33.9
8.9
Crude Oil Prod
9.1
Crude Distill Hydro Treat
9.0
Ethylene Mfg (Naphtha Crack)
Packaging
0.09 Plastic
0.93 Paper
One-Way Plastic Pouch Fill & Seal
33.7
Outer Bag
27.6
Pitchers
1.06
6.2
56.2
Home Delivery
Store Delivery
Postconsumer Solid Waste
62.4

Figure 23. Flow diagram shows delivery of 1,000 gallons of milk in nonrefillable plastic gallon pouches (in pounds).

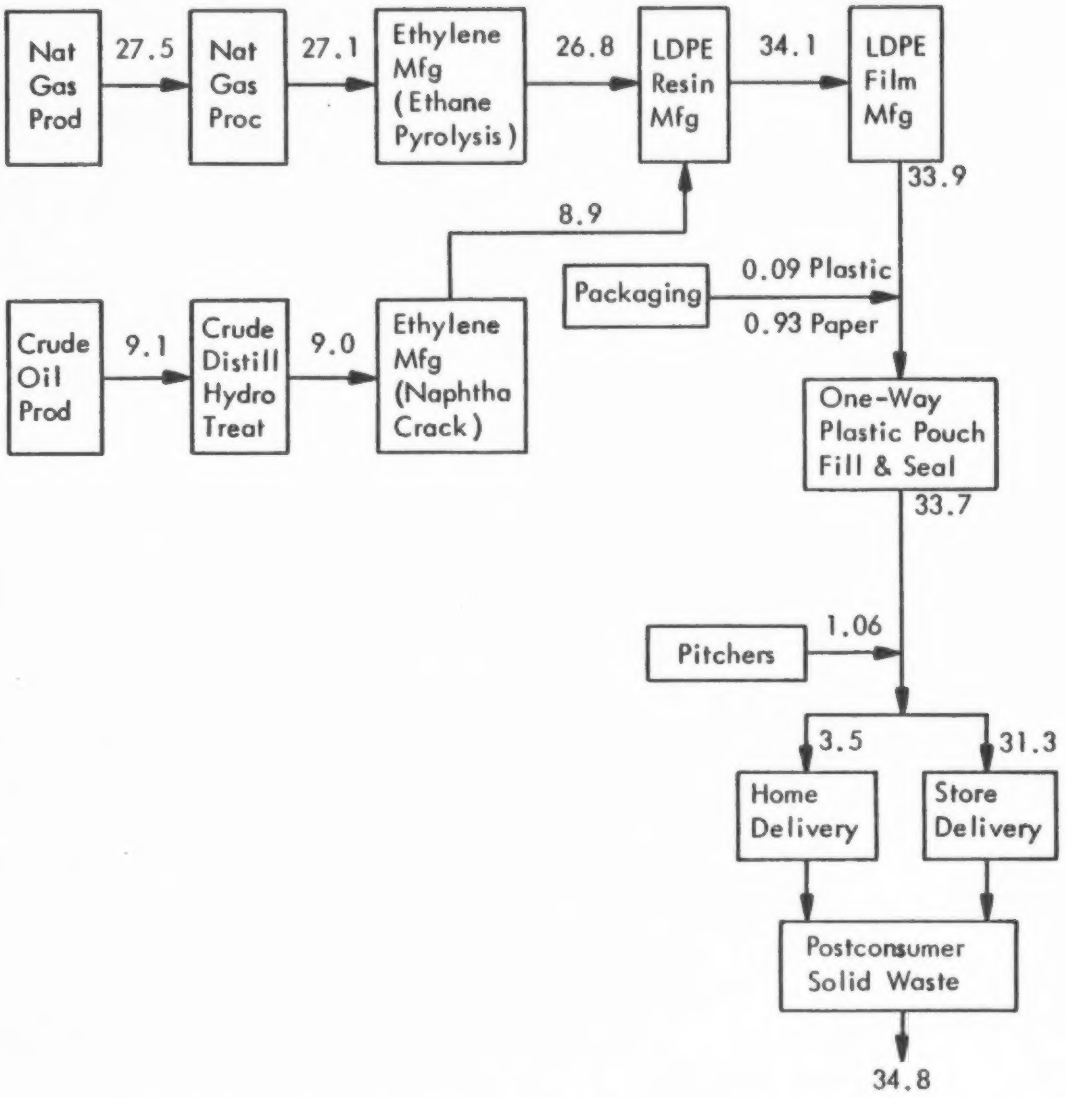

Nat Gas Prod
27.5
Nat Gas Proc
27.1
Ethylene Mfg (Ethane Pyrolysis)
26.8
LDPE Resin Mfg
34.1
LDPE Film Mfg
33.9
Crude Oil Prod
9.1
Crude Distill Hydro Treat
9.0
Ethylene Mfg (Naphtha Crack)
8.9
Packaging
0.09 Plastic
0.93 Paper
One-Way Plastic Pouch Fill & Seal
33.7
Pitchers
1.06
3.5
31.3
Home Delivery
Store Delivery
Postconsumer Solid Waste
34.8

Figure 24. Flow diagram shows delivery of 1,000 gallons of milk in nonrefillable plastic half gallon pouches (in pounds).

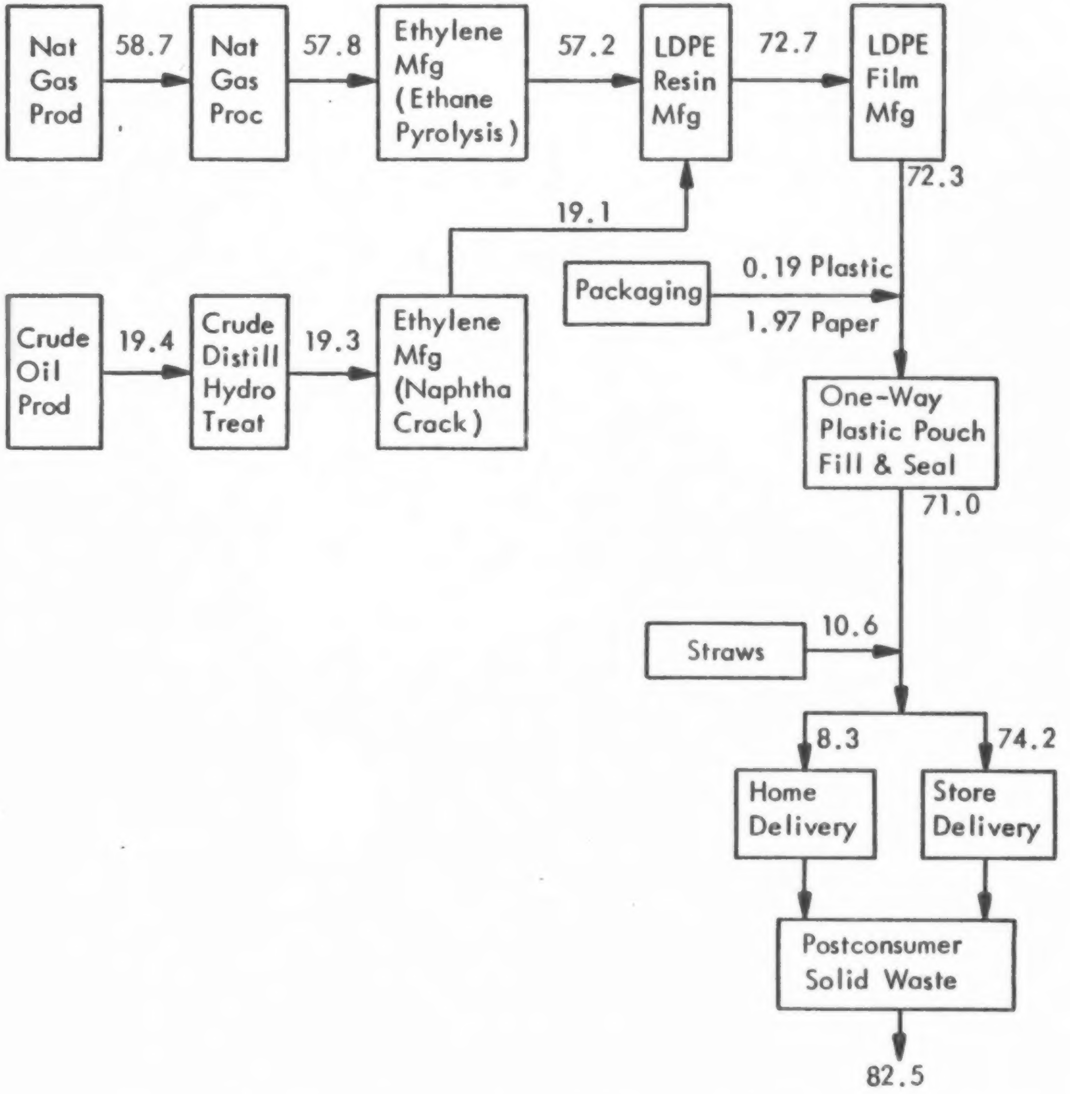

Nat Gas Prod
58.7
Nat Gas Proc
57.8
Ethylene Mfg (Ethane Pyrolysis)
57.2
LDPE Resin Mfg
72.7
LDPE Film Mfg
72.3
Crude Oil Prod
19.4
Crude Distill Hydro Treat
19.3
Ethylene Mfg (Naphtha Crack)
19.1
Packaging
0.19 Plastic
1.97 Paper
One-Way Plastic Pouch Fill & Seal
71.0
Straws
10.6
8.3
74.2
Home Delivery
Store Delivery
Postconsumer Solid Waste
82.5

Figure 25. Flow diagram shows delivery of 1,000 gallons of milk in nonrefillable plastic half pint pouches (in pounds).

TABLE 31

IMPACTS FOR 1,000 GALLONS OF THE NONREFILLABLE PLASTIC GALLON POUCH SYSTEM

		LDPE RESIN SYS 34.6 LB	LDPE FI LMB MFG 33.92 LB	PKG FOR POUCH SYS	FILL SEAL GALLON POUCH	PITCHER PLS PKG GAL PCH 27.52 LB	MILK DELIVERY PLS POUCH	GALLON POUCH SYS TRAN	PLS POUCH PCSW	TOTAL
INPUTS TO SYSTEMS										
NAME	UNITS									
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	.648	0.000	0.000	0.000	0.000	0.000	.648
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.234	.018	.005	.002	.202	.738	.047	.003	1.248
ENERGY SOURCE NAT GAS	MILL BTU	1.058	.018	.006	.002	.860	0.000	.006	0.000	1.950
ENERGY SOURCE COAL	MILL BTU	.126	.043	.003	.006	.136	0.000	0.000	0.000	.314
ENERGY SOURCE MISC	MILL BTU	.028	.010	.000	.001	.031	0.000	0.000	0.000	.070
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.005	0.000	0.000	0.000	0.000	0.000	.005
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	.900	0.000	.067	0.000	.720	0.000	0.000	0.000	1.687
ENERGY PROCESS	MIL BTU	.599	.089	.017	.012	.551	0.000	0.000	0.000	1.268
ENERGY TRANSPORT	MIL BTU	.017	0.000	.000	0.000	.014	.738	.052	.003	.824
ENERGY OF MATL RESOURCE	MIL BTU	.830	0.000	.002	0.000	.664	0.000	0.000	0.000	1.496
WATER VOLUME	THOU GAL	.069	.062	.001	.033	.105	.044	.003	.000	.317
OUTPUTS FROM SYSTEMS										
NAME	UNITS									
SOLID WASTES PROCESS	POUND	.824	.170	.065	.570	.797	0.000	0.000	0.000	2.425
SOLID WASTES FUEL COMB	POUND	.740	.255	.045	.034	.799	.179	.011	.001	2.063
SOLID WASTES MINING	POUND	2.015	.695	.044	.091	2.175	0.000	0.000	0.000	5.020
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.052	1.052
ATMOS PARTICULATES	POUND	.194	.054	.037	.007	.199	.078	.007	.000	.576
ATMOS NITROGEN OXIDES	POUND	.684	.094	.017	.012	.623	1.169	.140	.003	2.742
ATMOS HYDROCARBONS	POUND	1.754	.037	.014	.005	1.432	.670	.048	.003	3.962
ATMOS SULFUR OXIDES	POUND	.776	.239	.054	.031	.814	.220	.023	.001	2.157
ATMOS CARBON MONOXIDE	POUND	.137	.012	.006	.002	.119	3.840	.103	.118	4.336
ATMOS ALDEHYDES	POUND	.001	.000	.000	.000	.001	.047	.002	.000	.051
ATMOS OTHER ORGANICS	POUND	.002	.000	.008	.000	.002	.153	.004	.020	.188
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	0.000	.000	0.000	.000	.002	.000	.000	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	0.000	.000	.010	.000	.000	.010
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.190	.005	.006	.001	.156	.382	.024	.001	.764
WATERBORNE BOD	POUND	.009	.000	.019	.160	.007	.001	.000	.000	.197
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.001
WATERBORNE OIL	POUND	.002	.000	.000	.000	.002	.000	.000	.000	.004
WATERBORNE COD	POUND	.070	.000	.000	.000	.056	.004	.000	.000	.130
WATERBORNE SUSP SOLIDS	POUND	.022	.000	.009	.240	.018	.002	.000	.000	.292
WATERBORNE ACID	POUND	.039	.013	.001	.002	.042	.001	.000	.000	.097
WATERBORNE METAL ION	POUND	.010	.003	.000	.000	.010	.000	.000	.000	.024
WATERBORNE CHEMICALS	POUND	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	.001
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
NAME	UNITS									
RAW MATERIALS	POUNDS	.900	0.000	.715	0.000	.720	0.000	0.000	0.000	2.335
ENERGY	MIL BTU	1.446	.089	.019	.012	1.228	.738	.052	.003	3.588
WATER	THOU GAL	.069	.062	.001	.033	.105	.044	.003	.000	.317
INDUSTRIAL SOLID WASTES	CUBIC FT	.048	.015	.002	.009	.051	.002	.000	.000	.128
ATM EMMISSIONS	POUNDS	3.547	.435	.135	.057	3.188	6.190	.327	.144	14.024
WATERBORNE WASTES	POUNDS	.342	.022	.035	.403	.291	.391	.025	.001	1.510
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.052	1.052
ENERGY SOURCE PETROLEUM	MIL BTU	.234	.018	.005	.002	.202	.738	.047	.003	1.248
ENERGY SOURCE NAT GAS	MIL BTU	1.058	.018	.006	.002	.860	0.000	.006	0.000	1.950
ENERGY SOURCE COAL	MIL BTU	.126	.043	.003	.006	.136	0.000	0.000	0.000	.314
ENERGY SOURCE NUCL HYPWR	MIL BTU	.028	.010	.000	.001	.031	0.000	0.000	0.000	.070
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.005	0.000	0.000	0.000	0.000	0.000	.005
INDEX OF ENVIRONMENTAL IMPACTS										
NAME	STANDARD VALUES									
RAW MATERIALS	2.335	38.6	0.0	30.6	0.0	30.8	0.0	0.0	0.0	100.0
ENERGY	3.588	40.3	2.5	.5	.3	34.2	20.6	1.5	.1	100.0
WATER	.317	21.6	19.5	.2	10.6	33.1	14.0	.9	.0	100.0
INDUSTRIAL SOLID WASTES	.128	37.7	11.8	1.6	7.3	39.6	1.9	.1	.0	100.0
ATM EMMISSIONS	14.024	25.3	3.1	1.0	.4	22.7	44.1	2.3	1.0	100.0
WATERBORNE WASTES	1.510	22.6	1.4	2.3	26.7	19.3	25.9	1.6	.1	100.0
POST-CONSUMER SOL WASTE	1.052	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	1.248	18.7	1.4	.4	.2	16.1	59.2	3.7	.2	100.0
ENERGY SOURCE NAT GAS	1.950	54.3	.9	.3	.1	44.1	0.0	.3	0.0	100.0
ENERGY SOURCE COAL	.314	40.1	13.8	1.0	1.8	43.3	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.070	40.4	13.9	.1	1.8	43.6	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.005	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0

TABLE 32

IMPACT ANALYSIS--NONREFILLABLE PLASTIC POUCH GALLON SYSTEM

Impact category	Process with highest impact	Percent of total gallon pouch system
Raw materials	Resin system	38.6
Energy	Resin system	40.3
Water	Outer bag and pitcher	33.1
Industrial solid waste	Outer bag and pitcher	39.6
Atmospheric emissions	Milk delivery	44.1
Waterborne wastes	Fill and seal	26.7
Postconsumer solid wastes	PCSW	100.0

The milk delivery process for the gallon pouch system requires 20.6 percent of the energy for the entire system. The magnitude of the energy requirement, 0.738 million Btu, is the same as the milk delivery energy for the paperboard and the two plastic bottle systems. The percentage value is higher in the pouch system because fewer materials are required and therefore less energy is present as process and material resource energy.

The impact data for the half gallon and half pint pouch systems are shown in Tables 33 and 34.

In the half gallon system the resin subsystem dominates the impacts for the raw materials, energy, water, and industrial solid waste categories. Milk delivery shows the highest atmospheric emissions while the filling operation leads in waterborne wastes. The half gallon system does not require the use of a plastic outer bag, but does require a pitcher for serving purposes. Again milk delivery accounts for a considerable portion (31.2 percent) of the total system energy.

The impacts for the half pint pouch system (Table 34) show that the resin subsystem accounts for most of the impacts in each category except water volume. The 1,000 gallons of the half pint system requires 16,000 straws (10.58 pounds). The straw process contributes 10.5 percent of the total system energy. Milk delivery accounts for only 12.2 percent of the total system energy.

The resource and environmental impacts for 1,000 gallons of each pouch system are given in Table 35. In contrast to the other milk packaging systems, the one gallon container (two half gallon containers

TABLE 33

IMPACTS FOR 1,000 GALLONS OF THE NONREFILLABLE PLASTIC HALF GALLON POUCH SYSTEM

		LDPE RESIN SYS 34.60 LB	LDPE FILM MFG 33.92 LB	PKG FOR POUCH SYS	FILL SEAL HF GAL POUCH	PITCHER	MILK DELIVERY HF GAL POUCH	TRAN HGAL POUCH SY	HF GAL PLS PCH PCSW 34.60 LB	TOTAL
INPUTS TO SYSTEMS										
NAME	UNITS									
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	.065	0.000	0.000	0.000	0.000	0.000	.065
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.234	.018	.001	.002	.008	.738	.027	.001	1.029
ENERGY SOURCE NAT GAS	MILL BTU	1.058	.018	.003	.002	.033	0.000	.003	0.000	1.118
ENERGY SOURCE COAL	MILL BTU	.126	.043	.001	.006	.005	0.000	0.000	0.000	.181
ENERGY SOURCE MISC	MILL BTU	.028	.010	.000	.001	.001	0.000	0.000	0.000	.041
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	.001
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	.900	0.000	.009	0.000	.028	0.000	0.000	0.000	.937
ENERGY PROCESS	MIL BTU	.599	.089	.003	.012	.021	0.000	0.000	0.000	.724
ENERGY TRANSPORT	MIL BTU	.017	0.000	.000	0.000	.001	.738	.030	.001	.787
ENERGY OF MATL RESOURCE	MIL BTU	.830	0.000	.002	0.000	.026	0.000	0.000	0.000	.858
WATER VOLUME	THOU GAL	.069	.062	.000	.033	.004	.044	.002	.000	.214
OUTPUTS FROM SYSTEMS										
NAME	UNITS									
SOLID WASTES PROCESS	POUND	.824	.170	.009	.570	.031	0.000	0.000	0.000	1.604
SOLID WASTES FUEL COMB	POUND	.740	.255	.007	.034	.031	.179	.006	.000	1.252
SOLID WASTES MINING	POUND	2.015	.695	.011	.091	.084	0.000	0.000	0.000	2.896
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.583	.583
ATMOS PARTICULATES	POUND	.194	.054	.004	.007	.008	.078	.004	.000	.349
ATMOS NITROGEN OXIDES	POUND	.684	.094	.004	.012	.024	1.169	.079	.001	2.068
ATMOS HYDROCARBONS	POUND	1.754	.037	.006	.005	.055	.670	.027	.002	2.555
ATMOS SULFUR OXIDES	POUND	.776	.239	.008	.031	.031	.220	.013	.000	1.319
ATMOS CARBON MONOXIDE	POUND	.137	.012	.001	.002	.005	3.840	.059	.065	4.120
ATMOS ALDEHYDES	POUND	.001	.000	.000	.000	.000	.047	.001	.000	.049
ATMOS OTHER ORGANICS	POUND	.002	.000	.001	.000	.000	.153	.002	.011	.169
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	0.000	.000	0.000	.000	.002	.000	.000	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	0.000	.000	.010	.000	.000	.010
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.190	.005	.001	.001	.006	.382	.014	.001	.599
WATERBORNE BOD	POUND	.009	.000	.002	.160	.000	.001	.000	.000	.172
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE OIL	POUND	.002	.000	.000	.000	.000	.000	.000	.000	.003
WATERBORNE COD	POUND	.070	.000	.000	.000	.002	.004	.000	.000	.077
WATERBORNE SUSP SOLIDS	POUND	.022	.000	.001	.240	.001	.002	.000	.000	.267
WATERBORNE ACID	POUND	.039	.013	.000	.002	.002	.001	.000	.000	.056
WATERBORNE METAL ION	POUND	.010	.003	.000	.000	.000	.000	.000	.000	.014
WATERBORNE CHEMICALS	POUND	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
NAME	UNITS									
RAW MATERIALS	POUNDS	.900	0.000	.074	0.000	.028	0.000	0.000	0.000	1.002
ENERGY	MIL BTU	1.446	.089	.006	.012	.047	.738	.030	.001	2.370
WATER	THOU GAL	.069	.062	.000	.033	.004	.044	.002	.000	.214
INDUSTRIAL SOLID WASTES	CUBIC FT	.048	.015	.000	.009	.002	.002	.000	.000	.078
ATM EMMISSIONS	POUNDS	3.547	.435	.023	.057	.123	6.190	.185	.080	10.641
WATERBORNE WASTES	POUNDS	.342	.022	.004	.403	.011	.391	.014	.001	1.188
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.583	.583
ENERGY SOURCE PETROLEUM	MIL BTU	.234	.018	.001	.002	.008	.738	.027	.001	1.029
ENERGY SOURCE NAT GAS	MIL BTU	1.058	.018	.003	.002	.033	0.000	.003	0.000	1.118
ENERGY SOURCE COAL	MIL BTU	.126	.043	.001	.006	.005	0.000	0.000	0.000	.181
ENERGY SOURCE NUCL HYPWR	MIL BTU	.028	.010	.000	.001	.001	0.000	0.000	0.000	.041
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	.001
INDEX OF ENVIRONMENTAL IMPACTS										
NAME	STANDARD VALUES									
RAW MATERIALS	1.002	89.9	0.0	7.4	0.0	2.8	0.0	0.0	0.0	100.0
ENERGY	2.370	61.0	3.8	.2	.5	2.0	31.2	1.3	.1	100.0
WATER	.214	32.0	28.8	.2	15.6	1.9	20.7	.7	.0	100.0
INDUSTRIAL SOLID WASTES	.078	62.2	19.5	.5	12.1	2.5	3.1	.1	.0	100.0
ATM EMMISSIONS	10.641	33.3	4.1	.2	.5	1.2	58.2	1.7	.8	100.0
WATERBORNE WASTES	1.188	28.8	1.8	.4	33.9	.9	32.9	1.2	.1	100.0
POST-CONSUMER SOL WASTE	.583	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	1.029	22.7	1.7	.1	.2	.8	71.7	2.6	.1	100.0
ENERGY SOURCE NAT GAS	1.118	94.6	1.6	.3	.2	3.0	0.0	.3	.1	100.0
ENERGY SOURCE COAL	.181	69.6	24.0	.4	3.2	2.9	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.041	69.7	24.0	.3	3.2	2.9	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.001	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0

TABLE 34

IMPACTS FOR 1,000 GALLONS OF THE NONREFILLABLE PLASTIC HALF PINT POUCH SYSTEM

		LDPE RESIN SYS 73.64 LB	LDPE FILM MFG 72.20 LB	PKG FOR POUCH SYS	FILL SEAL HF PINT PLS PCH	STRAWS	MILK DELIVERY HF PINT PLS PCH	TRAN HPINT POUCH SY	HF PINT PLS PCH PCS# 81.20 LB	TOTAL
INPUTS TO SYSTEMS										
NAME	UNITS									
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	1.379	0.000	0.000	0.000	0.000	0.000	1.379
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.498	.038	.011	.019	.077	.547	.056	.003	1.249
ENERGY SOURCE NAT GAS	MILL BTU	2.252	.038	.012	.019	.331	0.000	.007	0.000	2.659
ENERGY SOURCE COAL	MILL BTU	.268	.092	.006	.045	.052	0.000	0.000	0.000	.464
ENERGY SOURCE MISC	MILL BTU	.061	.021	.000	.010	.012	0.000	0.000	0.000	.104
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	.012	0.000	0.000	0.000	0.000	0.000	.012
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	1.916	0.000	.144	0.000	.277	0.000	0.000	0.000	2.336
ENERGY PROCESS	MIL BTU	1.275	.190	.036	.093	.212	0.000	0.000	0.000	1.805
ENERGY TRANSPORT	MIL BTU	.037	0.000	.000	0.000	.005	.547	.063	.003	.655
ENERGY OF MATL RESOURCE	MIL BTU	1.767	0.000	.005	0.000	.255	0.000	0.000	0.000	2.027
WATER VOLUME	THOU GAL	.146	.132	.001	.168	.048	.032	.003	.000	.524
OUTPUTS FROM SYSTEMS										
NAME	UNITS									
SOLID WASTES PROCESS	POUND	1.755	.361	.138	.760	.306	0.000	0.000	0.000	3.320
SOLID WASTES FUEL COMB	POUND	1.576	.543	.095	.266	.307	.130	.013	.001	2.932
SOLID WASTES MINING	POUND	4.289	1.479	.094	.725	.836	0.000	0.000	0.000	7.422
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.349	1.369
ATMOS PARTICULATES	POUND	.412	.115	.079	.056	.076	.058	.008	.000	.805
ATMOS NITROGEN OXIDES	POUND	1.456	.200	.037	.098	.239	1.007	.168	.004	3.208
ATMOS HYDROCARBONS	POUND	3.733	.078	.029	.038	.550	.447	.058	.004	4.938
ATMOS SULFUR OXIDES	POUND	1.651	.508	.116	.249	.313	.174	.028	.001	3.038
ATMOS CARBON MONOXIDE	POUND	.292	.025	.012	.012	.046	2.300	.125	.154	2.964
ATMOS ALDEHYDES	POUND	.002	.000	.000	.000	.000	.028	.002	.000	.034
ATMOS OTHER ORGANICS	POUND	.004	.000	.016	.000	.001	.086	.004	.025	.138
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	0.000	.000	0.000	.000	.001	.000	.000	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	0.000	.000	.005	.000	.000	.006
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.404	.011	.012	.005	.060	.278	.029	.002	.801
WATERBORNE BOD	POUND	.020	.000	.041	.160	.003	.001	.000	.000	.224
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE OIL	POUND	.004	.000	.000	.000	.001	.000	.000	.000	.006
WATERBORNE COD	POUND	.149	.000	.000	.000	.022	.003	.000	.000	.174
WATERBORNE SUSP SOLIDS	POUND	.048	.000	.019	.240	.007	.002	.000	.000	.316
WATERBORNE ACID	POUND	.082	.028	.001	.014	.016	.001	.000	.000	.142
WATERBORNE METAL ION	POUND	.021	.007	.000	.003	.004	.000	.000	.000	.036
WATERBORNE CHEMICALS	POUND	0.000	0.000	.002	0.000	0.000	0.000	0.000	0.000	.002
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	.000	0.000	.000	0.000	0.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS										
NAME	UNITS									
RAW MATERIALS	POUNDS	1.916	0.000	1.522	0.000	.277	0.000	0.000	0.000	3.715
ENERGY	MIL BTU	3.078	.190	.041	.093	.472	.547	.063	.003	4.487
WATER	THOU GAL	.146	.132	.001	.148	.040	.032	.003	.000	.524
INDUSTRIAL SOLID WASTES	CUBIC FT	.103	.032	.004	.024	.020	.002	.000	.000	.185
ATM EMMISSIONS	POUNDS	7.550	.926	.288	.454	1.226	4.108	.394	.188	15.133
WATERBORNE WASTES	POUNDS	.728	.047	.075	.423	.112	.285	.030	.002	1.701
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.369	1.369
ENERGY SOURCE PETROLEUM	MIL BTU	.498	.038	.011	.019	.077	.547	.056	.003	1.249
ENERGY SOURCE NAT GAS	MIL BTU	2.252	.038	.012	.019	.331	0.000	.007	0.000	2.659
ENERGY SOURCE COAL	MIL BTU	.268	.092	.006	.045	.052	0.000	0.000	0.000	.464
ENERGY SOURCE NUCL HYPWR	MIL BTU	.061	.021	.000	.010	.012	0.000	0.000	0.000	.104
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	.012	0.000	0.000	0.000	0.000	0.000	.012
INDEX OF ENVIRONMENTAL IMPACTS										
NAME	STANDARD VALUES									
RAW MATERIALS	3.715	51.6	0.0	41.0	0.0	7.4	0.0	0.0	0.0	100.0
ENERGY	4.487	68.6	4.2	.9	2.1	10.5	12.2	1.4	.1	100.0
WATER	.524	27.9	25.1	.3	32.2	7.7	6.2	.6	.0	100.0
INDUSTRIAL SOLID WASTES	.185	55.7	17.4	2.4	12.8	10.6	1.0	.1	.0	100.0
ATM EMMISSIONS	15.133	49.9	6.1	1.9	3.0	8.1	27.1	2.6	1.2	100.0
WATERBORNE WASTES	1.701	42.8	2.7	4.4	24.9	6.6	16.8	1.7	.1	100.0
POST-CONSUMER SOL WASTE	1.369	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0
ENERGY SOURCE PETROLEUM	1.249	39.9	3.0	.8	1.5	6.2	43.8	4.5	.3	100.0
ENERGY SOURCE NAT GAS	2.659	84.7	1.4	.6	.7	12.4	0.0	.3	0.0	100.0
ENERGY SOURCE COAL	.464	57.7	19.9	1.4	9.8	11.2	0.0	0.0	0.0	100.0
ENERGY SOURCE NUCL HYPWR	.104	58.4	20.1	.2	9.9	11.4	0.0	0.0	0.0	100.0
ENERGY SOURCE WOOD WASTE	.012	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0

in an outer bag) does not have the most favorable profile when compared with the half gallon size. The half gallon system has the lowest impacts in each impact category. The favorable profile of the half gallon system is attributed to the smaller amount of raw materials (hydrocarbon feedstock) required per unit volume of milk. The weight of plastic required for 1,000 gallons of half gallon containers is 33.5 pounds, while the gallon size requires 61.3 pounds (33.7 pounds for pouches + 27.6 pounds for outer bag) and the half pint requires 82.5 pounds (71.96 pounds for pouches + 10.58 pounds for straws) of plastic material.

TABLE 35

IMPACTS FOR 1,000 GALLONS OF EACH NONREFILLABLE PLASTIC POUCH SYSTEM

	Container system		
Impact category	Gallon	Half gallon	Half pint
Raw materials, lb	2.33	1.00	3.72
Energy, 10^6 Btu	3.59	2.37	4.49
Water, 10^3 gallons	0.32	0.21	0.52
Industrial solid wastes, ft^3	0.13	0.08	0.18
Atmospheric emissions, lb	14.02	10.64	15.13
Waterborne wastes, lb	1.51	1.19	1.70
Postconsumer solid wastes, ft^3	1.05	0.58	1.37
Energy source petroleum, 10^6 Btu	1.25	1.03	1.25
Energy source natural gas, 10^6 Btu	1.95	1.12	2.66
Energy source coal, 10^6 Btu	0.31	0.18	0.46
Energy source misc., 10^6 Btu	0.07	0.04	0.10
Energy source wood waste, 10^6 Btu	0.01	0.00	0.01

Source: Midwest Research Institute.

CHAPTER 5

PUBLIC HEALTH AND SANITATION CONCERNS

A. Introduction and Methodology

Since milk is an integral part of the daily diet of most Americans, its wholesomeness and purity are natural and important considerations. Following pasteurization and vigorous testing, the responsibility for the preservation of milk's wholesomeness rests with the container. This chapter explores the interrelationships between the milk, the type of container, and public health. Included in this investigation are the following five container systems: glass, polyethylene single service, polyethylene multiuse, polyethylene pouch, and paperboard laminate.

The scope of work for this investigation called for a review of existing regulations, and interviews with individuals and organizations involved with the packaging and distribution of fluid milk. Through these contacts, MRI was to identify concerns that have been raised regarding the ability of each of the five container systems to comply with existing regulations and standards and to review available supporting documentation for these concerns. In discharging this task, MRI reviewed the compendium of regulatory policy relative to milk packaging and contacted a total of 79 individuals and organizations, including 37 governmental regulatory agencies on the federal, state and local levels, 27 industry representatives, 10 associations and 5 dairies. A complete list of these contacts is provided in the Appendix to this report.

In introducing this section of the report, it is important to indicate the unique considerations, assumptions and limitations relative to the investigation and resultant conclusions. These include the following:

- The study focused only on milk packaging and not on regulations or practices relative to the procurement, treatment, or handling of the milk prior to packaging. The assumption was therefore made that all milk was safe and wholesome prior to packaging.

- Much of the information in the study was provided through contacts with individuals representing various agencies, companies and associations. This type of approach naturally involves an element of subjectivity which is not present in a purely technical review.

- No original research was conducted in the development of information for this study.

- Not all problems relating to milk in particular types of containers are reported to governmental regulatory agencies. Consumers who have complaints often refer these complaints to the store from which the milk was purchased, and the reporting may go no further. Thus, despite the extensive number of contacts made in this study, it is possible that some health-related complaints have been overlooked.

B. The Regulatory Structure Governing Milk Packaging

1. The Pasteurized Milk Ordinance (PMO): The purity and wholesomeness of the milk which is produced, packaged and sold to the American consumer is controlled by a comprehensive system of regulations administered by federal, state, and in some cases, local governments. While the federal government controls the chemical composition of the milk container, actual sanitation standards for milk are not federally enforceable. Rather, the federal government through the Public Health Service has established a model ordinance, the Pasteurized Milk Ordinance (PMO), which may be voluntarily adopted by state and local governments. Forty-two of the 50 states have adopted this ordinance, and the remaining 8* have enacted equivalent or even more stringent regulations. However, in all cases, enforcement is the prerogative of the lower levels of government.

The concept of the PMO was originally developed in 1924 by the Public Health Service to aid state and local milk control agencies in establishing milk sanitation standards. Now in its 13th revision (dated 1965) the PMO has been incorporated into federal specifications for procurement of milk and milk products, serves as the sanitary standard for milk served on interstate carriers, and is recognized by public health agencies, the milk industry, and many others as a national standard for milk sanitation.

The following regulations in the PMO relate specifically to milk containers:

Item 11p. Construction and Repair of Containers and Equipment - "All multiuse containers and equipment with which milk or milk products come into contact shall be of smooth, impervious, corrosion-resistant, nontoxic material; shall be constructed for ease of cleaning; and shall be kept in good repair. All single service containers, closures, gaskets, and other articles with which milk or milk products come in contact shall be nontoxic, and shall have been manufactured, packaged, transported, and handled in a sanitary manner. Articles intended for single service use shall not be reused."

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* California, Connecticut, Delaware, Massachusetts, Vermont, New Hampshire, Maine and Rhode Island.

(Paper, plastics, foil, adhesives and other container components shall comply with the requirements of the Federal Food, Drug and Cosmetic Act as amended.)

Item 12p. Cleaning and Sanitizing of Containers and Equipment - "The product contact surfaces of all multiuse containers, utensils, and equipment used in the transportation, processing, handling and storage of milk or milk products shall be effectively cleaned and shall be sanitized before each use."

(Residual bacteria count of multiuse and single service containers "shall not exceed one per milliliter of capacity or not over 50 colonies per 8 square inches (one per square centimeter) of product contact surface in three out of four samples taken at random on a given day. All multiuse and single service containers shall be free of coliform organisms.")

Item 13p. Storage of Cleaned Containers and Equipment - "After cleaning, all multiuse milk or milk product containers . . . shall be transported and stored to assure complete drainage, and shall be protected from contamination before use."

Item 14p. Storage of Single Service Containers, Utensils and Materials - "Single service caps, cap stock, parchment paper, containers, gaskets, and other single service articles for use in contact with milk and milk products shall be purchased and stored in sanitary tubes, wrappings, or cartons; shall be kept therein in a clean, dry place until used; and shall be handled in a sanitary manner."

Item 15p. Protection from Contamination - "Milk plant operations, equipment, and facilities shall be located and conducted to prevent any contamination of milk or milk products, ingredients, equipment, containers, and utensils . . ."

Item 18p. Bottling and Packaging - "Bottling and packaging of milk and milk products shall be done at the place of pasteurization in approved mechanical equipment."

Item 19p. Capping - "Capping or closing of milk and milk product containers shall be done in a sanitary manner by approved mechanical capping and/or closing equipment. The cap or closure shall protect the pouring lid to at least its largest diameter."

2. Related Regulations: In addition to the PMO, standards have been developed specifically for multi-use containers and for single service containers. These include:

a. FDA 7-Point Standards for Multiuse Containers: These standards were developed by the U.S. Public Health Service (FDA) in response to the development of the polyethylene multiuse container. In September of 1965, the Public Health Service approved this type of container for national use, provided that the plastic material comply with appropriate FDA requirements; that a device be installed in the filling line which can detect volatile organic contaminants of public health significance; that the container be constructed in compliance with the PMO; and that it not impart into the product pesticide or chemical contaminant levels in excess of FDA standards.

b. U.S. Public Health Service Publication 1465, "Fabrication of Single Service Containers and Closures for Milk and Milk Products": This document is the basis for single service regulations within the Interstate Milk Shippers Program. As such, it serves as a more detailed version of Appendix J to Item 11p. of the PMO which also relates to single service containers. The residual bacterial standard for single-service containers set by this document is no more than 1 colony for milliliter of capacity or not over 50 colonies per 8 square inches of product-contact surface in three out of four samples taken randomly on a given day. All single-service containers shall be free of coliform organisms.

Representative samples are taken at least quarterly and analyzed at an official laboratory, commercial laboratory, or industry laboratory approved by the state milk laboratory certifying agency or the Public Health Service, specifically for the examinations required under these standards. Procedures for obtaining samples and for the laboratory examination of these products are contained in a Manual of Recommended Methods for Sampling and Microbiological Testing of Single-Service Food Packages and Their Components. This manual was compiled in 1964 by the Microbiological-Biochemical Center of Syracuse University Research Corporation in cooperation with federal, state, and local health officials and representatives of the manufacturers concerned.

3. The Interstate Milk Shippers Program (IMSP): The PMO also serves as the basis for a cooperative federal-state program called the Interstate Milk Shippers Program, which is administered jointly by the National Conference of Interstate Milk Shippers and the Food and Drug Administration. The FDA, a branch of the U.S. Public Health Service, provides the guidelines through the PMO, evaluates and endorses the state programs, trains and certifies state personnel, and publishes a quarterly list of certified interstate milk shippers. However, the program is mainly administered and the standards enforced by the states themselves. Forty-nine of the 50 states, which include all states engaged in interstate milk shipping (Hawaii being the exception) participate in the IMSP, encompassing 150,000 dairy farms and more than 1,600 shippers.

The processing of all raw milk, fluid milk, and milk containers which are shipped between states is regulated by the IMSP. Under the program, the states establish inspection programs which provide a rating system to determine the sanitation standards within milk plants, dairy farms and other concerns who process and package pasteurized milk. In addition, single-service container and closure manufacture is regulated under the program. U.S. Public Health Service (PHS) Publication 1465, "Fabrication of Single Service Containers and Closures for Milk and Milk Products" serves as a guide to ensure the continued production of sanitary containers and closures. The states usually administer these programs, both to ensure uniformity and also because most local health departments have stopped conducting milk inspections.

Basically, the inspection program involves the assignment of a rating to each company participating in interstate milk shipments, be it a dairy, a container manufacturer, or a bottling plant. The rating is computed by deducting penalties for those standards which the company does not meet. Any company with a rating below 90 percent is not allowed to ship its products in interstate commerce. The list of companies meeting the rating standard is published by the FDA. In this manner, a dairy buying paperboard cartons, from an out-of-state supplier, or a grocery chain receiving milk shipments from outside the state can be assured of receiving wholesome, safe products.

The FDA, mandated under the Public Health Service Act "to eliminate the transmission of communicable disease in interstate commerce," would like to have the PMO and IMSP incorporated into federal regulation in order to formalize the standards and allow for federal enforcement to guarantee compliance. Accordingly, FDA has issued a Preproposal Draft of a revised (14th) version of the PMO, which is currently being reviewed by state public health agencies, the milk industry, and other interested parties. The revised PMO incorporates the rating system established under the IMSP, the FDA 7-Point Criteria for Multiuse Containers, the standards for single-service containers developed within the IMSP, and specific changes reflecting new technology in the industry.

4. The Federal Food, Drug and Cosmetic Act: A specific area of milk packaging in which the FDA has current jurisdiction is in the composition of the milk container. The Food, Drug and Cosmetic Act stipulates, "A food shall be deemed to be adulterated if its container is composed, in whole or in part, of any poisonous or deleterious substance which may render the contents injurious to health." This provision empowers the FDA to require that companies file a petition with the Food Additives Section specifying the raw materials being used in the manufacture of containers and how the containers will be constructed. The FDA then determines whether these materials are nontoxic and safe for this consumer application. This health concern, as related to milk container manufacture,

involves the use of materials containing substances which might leach out into and contaminate the milk. Since such contamination would constitute adulteration of the product by a food additive (considered an indirect additive since it was not intentionally added to the milk), the FDA governs container composition at a federal level.

C. Identified Areas of Concern

Following a review of all the foregoing regulations relating to milk packaging, contacts with the 79 individuals and organizations mentioned in the Introduction were initiated. These contacts were made by personal interviews, by written correspondence, and by telephone. The general query addressed to each was "Do you know of any public health concerns relating to any of the five container types (plastic returnable, plastic disposable, plastic pouch, glass or paperboard), and if so, do you have documentation in support of those concerns?"

More specific questions were addressed to those contacts specializing in particular facets of our study area, such as the Communicable Disease Center in Atlanta, Georgia; Graham Polytrip Company, the manufacturer of the plastic returnable bottle and contaminant detector; Syracuse University Research Corporation, which is active in sanitation testing of container materials; and others. Additionally, a significant amount of related and background information was elicited in the course of our contacts.

This investigation revealed three areas of concern regarding milk packaging:

- The absorption by the multiuse polyethylene container of chemical compounds which could represent a potential public health threat;
- The absorption by the multiuse polyethylene container of "nuisance substances" imparting flavor or odor changes to the milk; and
- The presence of foreign objects in returnable containers.

Discussions of these concerns are presented below:

1. The Absorption of Chemicals Representing a Potential Public Health Threat: This first concern was raised by a substantial number of individuals and organizations contacted during our study. The most serious potential problem relates to toxic chemicals, such as petroleum products and pesticides, which can be stored in the polyethylene containers by consumers prior to returning the container to the store. Since polyethylene is known to absorb certain chemical compounds, there is a danger of these compounds

remaining in the container following washing and sanitization. If not subsequently detected by the sensing device (mandatory for multiuse plastic filling lines), these compounds may ultimately contaminate the milk. And, if contamination levels are high enough, such levels could lead to illness in the consumer.

Washington State University (WSU) did the initial studies on the container in 1963 (Ref. 18, 19), concluding that such absorption did occur and that the detection of such chemicals prior to reuse of the container was mandatory to circumvent their potential for creating a public health hazard. WSU recommended that a detection device be developed which would employ flame ionization as a means of identifying containers which had absorbed the chemicals in question. This same conclusion was reached in 1967 by the Polymer Service Laboratories in a report entitled "Contamination Level in Returnable Milk Bottles used in Temporary Solvent Storage" (Ref. 13).

The above results led the developers of the multiuse PE container system to design a detection system which would identify and destroy containers which had been contaminated with volatile organic substances. The detector is basically a hydrogen flame ionization device which draws air from inside the bottle through the sensing or detection device. Because of its method of operation, this device is commonly referred to as an electronic snifter. When the snifter detects a contaminant in excess of tolerance levels established by the FDA, a punch mechanism is activated, which punctures a hole in the container, rendering it unusable. The FDA has required a minimum sensitivity for the contaminant detector equivalent to a concentration of 10 ppm of methane or cyclohexane (used as a standard).

Following the development of such a detection device, the U.S. Public Health Service (PHS) permitted the experimental use of the multiuse container in one dairy in Spokane, Washington, in September 1964. By September 1965, the PHS had expanded its approval to a national level, providing that the 7-Point Standards for multiuse containers were met. These criteria included the stipulation that the detection device be used on the filling line, that it be set at a predetermined sensitivity level which could not be altered by the operator, that it be fitted with only single-service, nonscrew closures, and that the container not impart pesticide residue levels or other chemical contaminants in excess of those considered acceptable by the FDA. Other points amplified the provisions of Item 11p. of the PMO to make them directly applicable to the multiuse container.

This 1965 FDA approval was subsequently reaffirmed on June 28, 1968, after an evaluation of studies by the Wisconsin Alumni Research Foundation (WARF) and the Food Protection Research Laboratory, National Center for Urban and Industrial Health, Public Health Service.

Subsequent to the FDA approval of the multiuse container system and the related studies described above, several investigations have been conducted which question the safety of the container. These studies raise two basic issues relating to the multiuse container system as it affects the public health:

- The detector device does not pick up chemical contaminants other than volatile organics.
- The device is not as efficient as it should be; i.e., the sensitivity level may be altered or the destruct mechanism circumvented.

Perhaps the best known study questioning the safety of the multiuse container was conducted by Floyd W. Bodyfelt et al., of Oregon State University. Dr. Bodyfelt has been involved in testing the multiuse container since 1971. His results have been summarized in a paper entitled, "A Critical Study of the Multiuse Polyethylene Plastic Milk Container System (Ref. 6). Testing 16 chemical substances referred to as common in the home, Bodyfelt noted that the detector responded only to those containers contaminated with compounds classified as volatile hydrocarbons (a conclusion accepted as the standard capability of the hydrogen flame ionization detector). The detector did not respond to containers treated with DDT in wettable powder form, malathion, 2, 4-D, or the toxic salts lead arsenate and copper sulfate.

Contamination levels in the container treated with DDT wettable powder solution reached 0.28 and 0.29 ppm, respectively, at the 7- and 14-day tests. This is significantly higher than the 0.05 tolerance limit for DDT set by the FDA. Similarly, malathion showed 0.08 ppm, compared to the FDA 0.02 ppm tolerance level. The 2,4-D and the lead arsenate and copper sulfate all showed an insignificant amount of residual, registering below the detection limits of the method.

In Bodyfelt's opinion, this experiment indicates a potential for a health hazard since pesticides can conceivably be stored in the multiuse container and not be detected by the hydrogen flame ionization device. He believes that the detector "should have the operational capability, sensitivity, and reliability to readily detect significant levels of all or most chemical substances that are potentially injurious to human health" (Ref. 6).

MRI contacted the Dairy and Lipid Products Branch of FDA regarding the potential contamination of milk by pesticide residuals. FDA is aware of Bodyfelt's work and is monitoring the situation with returnable PE containers. The agency takes the position that the snifter detection system is providing adequate protection at the present time, but that the system is being constantly evaluated for possible hazards or deficiencies.

Another critical study was done by Franklin Clark of the Region X Food and Drug Administration in Seattle, Washington (Ref. 10). Clark cites 112 consumer complaints received by milk regulatory officials in Region X (Oregon, Washington and Idaho) during 1970 which related to multiuse plastic containers. Of these 112 complaints, there were 14 reported cases of illness associated with the consumption of fluid milk from multiuse plastic containers; however, these were not all confirmed.

Clark also checked the compliance of the container with the Food, Drug and Cosmetic Act, the PMO, and the 7-Point Criteria. He found 14 specific violations with eight enforcement actions, ranging from slack-filling problems to malfunctions of the detector. His survey also showed that Oregon and Idaho health officials rated the total process (including the container itself and the snifter device) as meeting requirements less than 80 percent of the time. Washington health officials believed that the process and snifter usually met requirements, but the container itself ranked between an 80 and 100 percent compliance with the above regulations.

Clark concluded from his study that the process, the container and the snifter do not meet the requirements of the PMO and the 7-Point Criteria. Points noted in conclusion were that extended use of the containers makes them more susceptible to the absorption of hydrocarbons; that mechanical malfunctions often result in the detector being bypassed; that the detector is not sealed as required; and that it is limited to detecting only volatile hydrocarbons.

In a further attempt to discern the extent of the public health threat posed by the contamination potential of multiuse PE containers, MRI contacted Dr. Marcus Horowitz of the Center for Disease Control in Atlanta, Georgia (Ref. 28). With regard to milk, the following reported outbreaks of illness were on record:

	TYPE OF OUTBREAK			
Year	Bacterial	Chemical	Unknown	Total
1974	2	--	2	4
1973	1	--	2	3
1972	--	1	--	1
1971	--	1	1	2
1970	1	1	2	4

On further investigation, the reported chemical outbreak in 1972 was determined to be a heavy metal poisoning unrelated to either fluid milk or package type. The chemical poisoning outbreak on January 13, 1971, occurred in Seattle, Washington. Two people were exposed to milk from a multiuse

PE container contaminated with a hydrocarbon listed as either gasoline or kerosene. Reported symptoms were dizziness, back pain, blurred vision, and a burning sensation in the mouth and throat. The duration of the illness was 24 hours, after which time there was full recovery.

In 1970, another chemical poisoning outbreak was reported, again from Seattle, Washington. In this instance, four people were exposed to milk from a returnable PE container contaminated with a petroleum product. Three of the four persons exposed became ill, complaining of gastrointestinal involvement and a petroleum aftertaste. The duration of illness in these cases was from 2 to 8 hours, with full recovery.

No outbreaks of chemical contamination through exposure to milk have been reported since 1972. The Center receives its information from state epidemiologists, who transmit the information via a "Foodborne Disease Surveillance Form." Dr. Horowitz believes that if the state epidemiologists receive notice of complaints from the local health agencies, they will in turn report them to the Center.

MRI also contacted Dr. Jane Wyatt, Consumer Officer for the Department of Agriculture in the State of Oregon, where the returnable PE container system has had relatively extensive application (Ref. 51). This Department acts upon complaints received through the Health Division. Dr. Wyatt stated that the department records a certain number of complaints each year regarding milk purchased in returnable polyethylene containers. These generally involve foreign matter, solvent and/or gasoline contamination, off-flavor or spoilage. Their records indicate three complaints of illness in 1970. Milk samples in each complaint were analyzed. In one case the sample was negative for pesticide and hydrocarbons; the others showed 12 ppm for gasoline and 0.5 ppm for gasoline, respectively. In 1974, the department received a complaint of an off-odor in milk. Laboratory analysis showed 0.1 ppm malathion; however, none of the product was consumed and no illness was involved. The container was subjected to a snifter device at a local commercial dairy plant, and the device failed to detect the contamination. An additional illness involving an infant was reported to an Oregon dairy in 1970, allegedly caused by a residual of Pine-Sol detergent in a PE milk container. The incident was not, however, officially reported to the Oregon Department of Agriculture and is thus not verifiable through their records. Overall, the number of illnesses reported represents a very small percentage of the total volume of returnable PE containers used in Oregon. Furthermore, Dr. Wyatt indicated that the biggest problem associated with this container system was of a nuisance nature rather than a true public health problem.

In support of the multiuse container system, Graham Polytrip, the manufacturer of the detection device, has taken the following positions in regard to the issues raised by the public health investigations of the multiuse PE container system (Ref. 23):

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a. Issue: The detector does not pick up chemical contaminants other than volatile organics.

Graham's Response: The detector was developed to pick up those contaminants which can be absorbed by polyethylene, i.e., quasi- and nonpolar chemicals. These compounds are basically of a hydrocarbon nature and are the contaminants found "almost exclusively" in the multiuse container. The cases of illness reported have involved only hydrocarbon contaminants. Other contaminants which could conceivably be introduced into the container would most likely be removed in the wash cycle.

Most pesticides, according to Graham's investigation, have a hydrocarbon carrier and would therefore respond to the detector. Studies by the Wisconsin Alumni Research Foundation (WARF) examined pesticide residuals in milk.* Concentrations of 2,4-D, malathion and DDT (25 percent higher than manufacturers' recommendations) were stored in plastic bottles for 4 weeks; then the bottles were emptied, conventionally washed, filled with milk and stored for 10 days at 45 ° F. Analysis of the milk showed 0.08 to 0.084 ppm for DDT, less than 0.03 ppm for 2,4-D and 0.03 to 0.04 ppm for malathion.

Graham's response to Bodyfelt's study is that the only contaminants not detected by the Polytrip system and reported at significant values by chemical analysis were the wettable powder DDT and malathion, at 0.29 and 0.08 ppm. The toxic salts showed negative results in terms of residuals in the milk, providing no evidence that these compounds are absorbed by the polyethylene.

Furthermore, Graham contends that the FDA, by setting the sensitivity level of the sniffer at 10 ppm while recognizing a 0.05 ppm tolerance limit for DDT and a 0.02 ppm tolerance for malathion, has in effect supported their position that the majority of contaminants typically found in multiuse containers are hydrocarbons themselves or are emulsified in a hydrocarbon carrier and would be detected at the 10 ppm level set by FDA.

b. Issue: The detector device is not as efficient as it should be; i.e., it does not pick up all hydrocarbon contaminants because of alterations in the sensitivity level, and its punch mechanism may be circumvented.

Graham's Response: Graham states that the detector has "evolved as a safe and reliable process instrument that functions as intended with a minimum of service." The detector is permanently installed on the conveyor line between washer and filler. The device stops the bottle for analysis and does not release it until it has been determined to be below the established rejection level; if it is above this level, the bottle is punched by a piercing awl which renders the bottle unusable.

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* Results of the WARF studies were taken from correspondence received from Graham Polytrip. It was Graham's position not to make these proprietary studies available to MRI.

The device is made to be adjustable in order to accommodate different sizes of containers, so it is impossible to fix the destruct mechanism permanently. Thus, "deliberate attempts to render the instrument inoperational are possible." Graham does not believe that a foolproof system can be devised, but they do feel that they have developed adequate safeguards to assure proper operation. These include:

- A testing device on the detector, involving a cylinder of "span" gas of a certified concentration of hydrocarbons in air equivalent to the rejection level set by the FDA. This procedure is recommended to all their customers on a daily basis to ensure proper functioning of the detector-destruct system.

- Loss of the flame renders the detector inoperative. Furthermore, the system is designed so that loss of air or electricity stops the bottle line.

In response to questions regarding malfunctions of the detector which would encourage dairies to bypass it, Graham notes that their policy of inspection and repair every 3 months will allow trouble-free operation during the year. They also stress to plant personnel the importance of checking the device daily prior to beginning a bottling run.

FDA also believes that the detectors function fairly well on a daily basis because companies must maintain a high level of quality control to protect themselves from federal penalties and consumer complaints (Ref. 43).

2. The Absorption of "Nuisance Substances" Imparting Flavor or Odor Changes: Many of the complaints related to the absorption tendencies of polyethylene do not represent health hazards but rather are a nuisance to the consumer. Such complaints deal with the off-odors and off-flavors imparted to the milk by substances absorbed by the container. Basically, these nuisance-type flavor and odor problems are caused by:

a. Compounds absorbed by the polyethylene which do not pose a health problem, such as orange juice and fruit punch;

b. Compounds absorbed by the polyethylene at levels below the accepted tolerance limits set by the FDA, but sufficient to impart an odor, such as small amounts of petroleum;

c. Milk fats.

Clark's study cites 30 off-flavor and 25 off-odor complaints out of the total 112 received in FDA Region X in 1970 (Ref. 10). He speculates that many more complaints are received by stores, processors and distributors. Similarly, Wyatt reports numerous flavor and odor problems with the multiuse container in Oregon, and the New Hampshire Health Department has had documented instances of odor and flavor complaints relating to milk in multiuse containers from one company. That company has since changed to single-service containers. The Connecticut Health Department has had similar experiences with odor and flavor complaints, and several companies have adopted the single-service bottle because of this problem.

The absorption of milk fats by polyethylene has been studied in depth by Wildbrett in Germany (Ref. 49). He concluded that polyethylene demonstrated an affinity for lipids, which increases with the number of times the containers are used. Repeated usage causes "stress cracking" of the container, thus increasing fat absorption. Additionally, the fatty impurities have greater adhesion than that of the cleaning solution, making it difficult to remove the fats through the routine washing process. The absorption of milk fat "may promote the development of stale or lack-of-freshness type off-flavors, or catalyze the development of an oxidized flavor, especially after a portion of the contents is consumed and oxygen accumulates in the container headspace."

It should be emphasized again that off-odor and flavor complaints not related to compounds posing a health problem or to levels of such compounds in excess of acceptable limits are only nuisance problems and do not represent a public health hazard. They are cited here solely to provide the reader with a general understanding of the status of the multiuse container.

3. The Presence of Foreign Materials in Returnable Containers: The two returnable container systems subject to this consideration are glass and blow-molded PE bottles. Because of the diminished visibility offered by the PE bottle, this container system has borne the brunt of criticism regarding the retention of foreign materials. The most common consumer complaints received by local regulatory agencies are of mold and dried milk either found floating in the milk or adhering to the walls of the container. Foreign materials left in a returnable container after the washing and sanitizing cycle constitute a violation of the PMO Item 12p., calling for product contact surfaces to be effectively cleaned and sanitized before each use.

In considering the cleanability of the two multiuse container systems studied (glass and polyethylene), the foreign materials problem was relegated by those contacted to the status of a nuisance or aesthetic problem rather than a public health concern. According to several sources, the explanation for this situation lies in the stringent washing requirements established and practiced in the dairies. Returnable PE bottles are given essentially the same washing procedure as glass bottles. Containers are washed thoroughly, treated with caustic solution and given a chlorine rinse. The initial washing phase cleans the debris from the container, and the caustic solution completes the cleaning process and initiates destruction of bacteria. The final chlorine rinse effectively disinfects the product contact surface and any foreign material which may yet be adhering to the walls of the container (Ref. 48).

In summary, MRI's investigation revealed three concerns relating to the returnable PE container, only one of which has real public health implications; i.e., the absorption of potentially hazardous chemical compounds. The data presented indicates a general awareness of this concern among industry, dairy scientists and the FDA. Given this level of awareness and the monitoring of the situation by FDA, it would appear that adequate safeguarding procedures, reflective of the federal regulatory mandate, are being followed. Additionally, should the situation change (e.g., if additional data become available) the existing regulatory mechanism would be able to respond to such changes and make the alterations necessary to protect the consumer.

CHAPTER 6

THE EFFECTS OF LIGHT ON FLAVOR AND NUTRITION

A. Introduction and Methodology

Since milk provides a significant source of nutrients for many Americans, its quality in terms of flavor and nutrition has been a vital concern for food scientists, milk producers and milk distributors. Especially for children, milk is an important source of such nutrients as protein, riboflavin, calcium and Vitamin D.

The adverse effects of light on milk have long been recognized in the scientific community and the milk industry. Light can (1) act as a catalyst in the development of off-flavors, (2) deplete specific nutrients in the milk, notably ascorbic acid (Vitamin C) and riboflavin. Numerous studies have been conducted to determine the mechanisms of the flavor change, to quantify nutritional losses, and to define the effects of container type, light intensity and length of exposure on the basic reactive process.

It is the purpose of this chapter to examine the impacts of the light reaction on the various container types. In order to accomplish this, an extensive literature review has been done, with emphasis on those studies which used package type as a variable. Additionally, contacts were made with certain individuals and organizations knowledgeable in this area; these contacts are included in the appendix to this report.

B. Impacts of Light on the Various Container Types

Studies have been published since 1907 on the light exposure of milk. For many years, only sunlight or daylight were considered, but with the advent of fluorescent lights and their widespread use in supermarket dairy cases, the trend has been to study the effects of artificial lights, especially the fluorescents.

Other changes in the marketing and distribution of milk have also altered the focus of recent studies. While in the past, milk was channeled from the farm to the consumer in as little as 24 to 48 hours, today's technology and marketing techniques have expanded this time frame to as much as 7 days. A 1974 nationwide survey, conducted by Market Facts, Inc., examined the storage period of 58,973 milk containers of all types and sizes in 105 different supermarkets (Ref. 36). They found that 71 percent of the containers remained in the dairy case over 5 hours, 58 percent after 8 hours, and 37 percent were still unsold after 24 hours. The survey also determined that the average light intensity in the dairy cases was approximately 200 footcandles, though in some areas averages of as high as 387 footcandles were reported. Other studies have indicated readings as high as 700 footcandles.

Given the longer storage times combined with such high light intensities, protection of milk from exposure by the container in which it is packaged becomes increasingly important. The advent of the plastic returnable and disposable jugs has created increased concern about light effects because the plastic material transmits a greater amount of light than the conventional paperboard container.

There is general agreement in the literature that the package which permits the least amount of light transmission is the most effective in protecting the milk from off-flavor development, as well as from nutrient loss. Generally, clear glass bottles offer the least protection, with plastic bottles providing equally poor or only slightly better protection. Amber glass and wax-coated paper range about medium in protective quality, while PE-coated paper, especially when printed with low-light-transmission inks, is generally considered to be highly protective. Percentages of light transmission of glass, plastic and paperbord at varying light intensities are shown in Table 36.

TABLE 36

PERCENTAGE OF LIGHT TRANSMISSION

	100 foot-candles (%)	200 foot-candles (%)	300 foot-candles (%)	400 foot-candles (%)
Uncolored fiberboard	2.8	2.6	2.8	3.0
Plastic	66	67.5	72	75
Glass	94	90	92	89

Source: Ref. 11.

C. Flavor

Although many factors contribute to the development of off-flavors in milk, light is the primary concern of this section of the report. Since light does have a well-established, consistent effect on milk, and since its action on the product can be diminished by certain types of packaging, it has become one of the most significant subjects of scientific studies on off-flavor development in dairy products.

Many studies have been done on light effects and package types; however, only a few are directly comparable in that they deal with similar containers exposed to similar conditions. In three studies by Dimick (14), Sattar and de Man (39), and Coleman (12), flavor tests were conducted on milk in different package types which were exposed to 100 footcandles of light.

In Dimick's study, the flavor of the milk from the plastic and glass containers was comparable, showing rapidly decreasing values on the hedonic scale (a subjective ranking from "like" to "dislike" of the milk flavor) between 3 and 12 hours of exposure, using trained and expert taste panels. Milk in paperboard containers did not reach similarly low values until it had been exposed for 48 hours. Sattar and de Man found "significant" off-flavor development after 12 hours exposure to 100 footcandles with the paperboard carton and "highly significant" flavor change with the plastic jug at the same time interval. At 200 footcandles, significant change was noted after 3 hours with the plastic jug and after 12 hours with the carton. Again, only trained and expert tasters were utilized. Finally, in Coleman's study, light-induced flavor change was noted within 12 hours for milk in plastic and glass containers, but no drastic change was noted even after 144 hours in paperboard. Coleman added a consumer taste panel to his trained panel; as could be expected, the consumers were less critical than the professionals.

None of the studies in the literature review tested a plastic pouch such as is currently on the market. Although Sattar tested a clear pouch and an opaque pouch, his results are not comparable to the existing pouch product, which is partially covered with colored ink. Coleman's study indicates that inks provide considerable protection for the milk product. Pitcher Pak, one of the primary manufacturers of the plastic pouch, contends, "The pouch is protected the same as the carton by a lay-down of ink," and "there is nothing inherent in either to protect milk from light degradation." MRI suggests that this statement may be in variance with studies by Dimick and Coleman cited earlier, which directly compare unprinted paperboard to a clear plastic bottle and show that the plastic develops off-flavors much sooner than the unprinted paperboard. Since Sattar found that the clear pouch is directly comparable to the clear bottle, we can conclude that even unprinted paper is much more effective than clear plastic. It would appear to be true, however, that inks do improve the protective quality of the pouch, although not to as great a degree as Pitcher Pak indicates.

Despite the findings that paperboard containers provide better protection against off-flavor development, the implications of this situation are unclear. Some representatives within the milk industry feel that the presence of an off-flavor discourages consumers from buying milk and therefore deprives them of its nutrients. These individuals therefore conclude that off-flavor development directly correlates with nutritional loss and should be considered as a public health concern. MRI found no studies which could support such a correlation. First, there is no evidence that decreases in per capita milk consumption are caused by off-flavor development. Second, none of the studies address the impact of decreased per capita milk consumption on overall nutritional intake. In the absence of such data, MRI submits that no definitive argument can be made that light-induced off-flavor development in milk is a public health concern.

D. Nutrition

The nutritional content of milk is highly scrutinized by the U.S. Food and Drug Administration, with specific regulations provided under FDA's Information Panel and Nutritional Labeling regulations. Table 37 shows the nutrients contained in typical vitamin A and D fortified nonfat milk, and the percentage of U.S. Recommended Daily Allowance supplied by each nutrient. As indicated, milk is a significant source of calcium, riboflavin, vitamin D, phosphorus, vitamin B12 and protein.

TABLE 37

PERCENT OF U.S. RECOMMENDED DAILY ALLOWANCE PROVIDED BY A TYPICAL VITAMIN A AND D FORTIFIED NONFAT MILK

		U.S. RDA	Percent U.S. RDA Per Serving
Calcium	(grams)	1.0	30
Riboflavin	(milligrams)	1.7	25
Vitamin D	((intl. units)	400	25
Phosphorus	(grams)	1.0	20
Vitamin B 12	(micrograms)	6.0	15
Protein	(grams)	45	20
Vitamin A	(intl. units)	5,000	10
Vitamin B 6	(milligrams)	2.0	6
Thiamine	(milligrams)	1.5	6
Vitamin C	(milligrams)	60	4
Niacin	(milligrams)	20	* less than 2 percent
Iron	(milligrams)	18	* less than 2 percent

Source: Compiled from MIF Labeling Manual.

Although most nutritional labeling is voluntary, such labeling is required when a manufacturer adds any nutrient to a food product or when he makes some nutritional claim for it on the label or in advertising. This condition is especially applicable to milk, since virtually all milk is now fortified with vitamins A or D. Whenever nutritional labeling is used, the label must conform to a certain format, which indicates serving sizes, servings per container, caloric content, protein content, carbohydrate content, fat content, and percentage of U.S. Recommended Daily Allowances (RDA) represented by each nutrient. In the case of foods commonly consumed more than once a day, such as milk, the label may include a second column of nutrient figures showing the quantities contained in the amount to be consumed in a day as well as in a single serving.

Under the Information Panel section of this legislation, the FDA requires that all required food labeling information, including nutrition labeling, be printed prominently and conspicuously on the principal display panel or the information panel, and that the letters or numbers not be less than 1/16-inch in height. However, the Act provides that if the label of the package is too small to accommodate printing that meets these requirements, the manufacturer may petition the FDA for an exception, substituting an alternative method of displaying the requisite information.

There are known variations in the nutritional values of milk, due to such factors as seasonality, differences in the food intake of individual dairy cows, geographic variances, and differences in exposure to light. A number of studies have been done on the effects of light on the various nutrients, predominantly on riboflavin and ascorbic acid, but also on vitamins A, B_1 (thiamine), B_6 and niacin. Dimick (14), Sattar (39), Hedrick and Glass (27), and Hansen and Aurand (26) studied the impact of light on riboflavin and ascorbic acid content in the various container types. Thompson (46) also investigated losses of vitamin A supplementation through light exposure. The general consensus of the literature is that riboflavin is minimally affected, with a maximum 20 percent loss following 144 hours of exposure to 200 footcandles; and that ascorbic acid eventually loses its potency in any type of container, regardless of light exposure. Vitamin A supplementation loss has been examined in only one study researched in the literature review, and the data is not considered sufficiently representative to be discussed here.

The nutritional variations which occur, from light exposure as well as the other factors mentioned, have been taken into account by the Milk Industry Foundation (MIF), which undertook a comprehensive study to establish guidelines for milk producers in developing nutrient labels. The product of this study, The MIF Labeling Manual, incorporates data gathered via a literature review, contacts with national dairy experts and actual product sampling (performed in accordance with FDA sampling procedures and allowing for such variables as seasonality, geographic region and retail handling). FDA has generally approved MIF's guidelines with the stipulation that processors are individually responsible for quality control to insure conformity with the MIF uniform values. The Manual notes that "the values. . . have been meticulously studied and subjected to the statistical parameters set forth by FDA in its "Compliance Procedures for Nutrition Labeling," and the MIF staff has concluded that if a processor closely adheres to predetermined standardization levels. . .he should have no problem in meeting the enforcement provisions" (Ref. 30, p. 29).

Given the stringent regulatory mechanism for nutrition labeling of milk, the work of the Milk Industry Foundation, and review of studies showing minimal loss of riboflavin, loss of ascorbic acid in all container types, and only preliminary indications of vitamin A supplementation losses, it would appear that no documented evidence exists to indicate significant nutritional losses associated with a particular container type. Again, were such losses to be substantiated, their implications in terms of overall nutritional impact on the consumer and thus on the public health would be extremely difficult, if not impossible, to establish.

APPENDIX

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS

This appendix presents the basic raw data used to develop the resource and environmental profile analysis of the five milk container systems.

Section A discusses the basic energy factors used in the study and identifies the impacts associated with the combustion of a unit quantity of fuel, and the impacts for generating and delivering electric energy. The impacts associated with the various modes of transportation are also included.

Sections B through F discuss the impacts associated with the basic processes making up the resource and environmental profile of each container system. In most processes the environmental impacts are presented for 1,000 pounds or 1,000 gallons of the process. Computer tables showing the total impacts for each process are presented in Section I.

Sections G and H present a brief description of the paper and plastic closure systems and the secondary packaging system.

A. Basic Energy Conversion Factors

This section contains data and information used to convert raw fuel and electric energy input values into corresponding environmental impact parameters. The basic factors are discussed in three sections:

1. Mobile and Stationary Sources;
2. Electric Energy; and
3. Transportation.

1. Mobile and stationary sources: A set of atmospheric emission factors resulting from the combustion of fuels has been developed by the authors of this report in cooperation with staff in the Physical Sciences Division of Midwest Research Institute (MRI). They are reported in Table I-37. These data represent both a comprehensive literature search and data collected from a nationwide telephone survey. The primary source was Reference 60, but numerous other literature sources were also used. The factors represent national average emissions after pollution controls have been applied. They are representative of projections of levels which will be experienced in 1975.

TABLE 38

FUEL FACTORS

	Gasoline (1000 gal.)			Diesel (1000 gal)			Fuel Oil Mobile Source (1000 gal)		
	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total
Energy-10⁶ Btu	19.9	125.0	144.9	19.9	139.0	158.9	19.9	150.0	169.9
Solid Wastes - lb	36.2		36.2	36.2		36.2	36.2		36.2
Atmospheric Emissions - lb									
Particulates	4.2	11.0	15.2	4.2	13.0	17.2	4.2	23.0	27.2
Nitrogen Oxides	34.7	120.0	154.7	34.7	370.0	404.7	34.7	105.0	139.7
Hydrocarbons	54.3	103.0	157.3	54.3	37.0	91.3	54.3	5.0	59.3
Sulfur Oxides	31.7	6.0	37.7	31.7	27.0	58.7	31.7	302.0	333.7
Carbon Monoxide	11.3	1030.0	1041.3	11.3	225.0	236.3	11.3	130.0	141.3
Aldehydes	0.4	12.0	12.4	0.4	3.0	3.4	0.4	10.0	10.4
Other Organics	0.5	44.0	44.5	0.5	3.0	3.5	0.5		0.5
Ammonia	0.4		0.4	0.4		0.4	0.4		0.4
Lead	0.003	3.0	3.0	0.003		0.003	0.003		0.003
Total Atmospheric	137.5	1454.0	1466.5	137.5	678.0	815.5	137.5	575.0	712.5
Waterborne Wastes - lb									
Dissolved Solids (oil field brine)	80.9		80.9	80.9		80.9	80.9		80.9
Other	3.1		3.1	3.1		3.1	3.1		3.1
Total Waterborne	84.0		84.0	84.0		84.0	84.0		84.0

	(1000 ft^3) Natural Gas Internal Combustion			(1000 ft^3) Natural Gas Industrial Heating			(1000 ft^3) Natural Gas Utility Heating		
	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total
Energy-10⁶ Btu	0.056	1.03	1.086	0.056	1.03	1.086	0.056	1.03	1.086
Solid Wastes - lb									
Atmospheric Emissions - lb									
Particulates	0.003		0.003	0.003	0.018	0.021	0.003	0.015	0.018
Nitrogen Oxides	0.357	6.0	6.357	0.357	0.214	0.571	0.357	0.600	0.957
Hydrocarbons	1.024	0.8	1.824	1.024	0.003	1.027	1.024	0.001	1.024
Sulfur Oxides	0.012		0.012	0.012		0.012	0.012		0.012
Carbon Monoxide	0.104	1.6	1.704	0.104	0.020	0.124	0.104	0.017	0.121
Aldehydes					0.002	0.002		0.001	0.001
Other Organics					0.005	0.005		0.003	0.003
Ammonia									
Lead									
Total Atmospheric	1.5	8.4	9.9	1.5	0.3	1.8	1.5	0.6	2.1
Waterborne Wastes - lb									
Dissolved Solids (oil field brine)	0.19		0.19	0.19		0.19	0.19		0.19
Other									
Total Waterborne	0.19		0.19	0.19		0.19	0.19		0.19

	(1000 gal.) Residual Oil Industrial Heating			(1000 gal.) Fuel Oil Utility Heating			(1000 gal.) Distillate Oil Indust. Heating		
	Pre-combustion	Combustion	Total	Pre-combustion	Pre-Combustion	Total	Pre-combustion	Combustion	Total
Energy - 10⁶ Btu	19.9	150.0	169.9	19.9	148.0	167.9	19.9	139.0	158.9
Solid Wastes - lb	36.2		36.2	36.2		36.2	36.2		36.2
Atmospheric Emissions - lb									
Particulates	4.2	23.0	27.2	4.2	8.0	12.2	4.2	15.0	19.2
Nitrogen Oxides	34.7	72.0	106.7	34.7	105.0	139.7	34.7	72.0	106.7
Hydrocarbons	54.3	3.0	57.3	54.3	2.0	56.3	54.3	3.0	57.3
Sulfur Oxides	31.7	250.0	281.7	31.7	254.0	285.7	31.7	142.0	173.7
Carbon Monoxide	11.3	4.0	15.3	11.3	3.0	14.3	11.3	4.0	15.3
Aldehydes	0.4	1.0	1.4	0.4	1.0	1.4	0.4	2.0	2.4
Other Organics	0.5		0.5	0.5		0.5	0.5		0.5
Ammonia	0.4		0.4	0.4		0.4	0.4		0.4
Lead	0.003		0.003	0.003		0.003	0.003		0.003
Total Atmospheric	137.5	353.0	490.5	137.5	373.0	510.5	137.5	238.0	375.5
Waterborne Wastes - lb									
Dissolved Solids (oil field brine)	80.9		80.9	80.9		80.9	80.9		80.9
Acid	0.2		0.2	0.2		0.2	0.2		0.2
Mital ion	0.1		0.1	0.1		0.1	0.1		0.1
Other	0.8		2.8	2.8		2.8	2.8		2.8
Total Waterborne	84.0		84.0	84.0		84.0	84.0		84.0

	Coal Industrial Heating (1000 lb)			Coal Utility Heat (1000 lb)			Diesel Locomotive (1000 gal)		
	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total
Energy - 10⁶ Btu	0.2	13.1	13.3	0.2	13.1	13.3	19.9	139.0	158.9
Solid Wastes - lb	190.0	31.0	221.0	190.0	69.0	259.0	36.2		36.2
Atmospheric Emissions - lb									
Particulates	2.0	21.0	23.0	2.0	11.0	13.0	4.2	25.0	29.2
Nitrogen Oxides	0.5	9.0	9.5	0.5	9.0	9.5	34.7	370.0	404.7
Hydrocarbons	0.5	0.5	1.0	0.5	0.15	0.65	54.3	94.0	148.3
Sulfur Oxides	1.5	42.0	43.5	1.5	55.0	56.5	31.7	57.0	88.7
Carbon Monoxide	2.5	1.0	3.5	2.5	0.5	3.0	11.3	130.0	141.3
Aldehydes	0.01	0.003	0.013	0.01	0.003	0.013	0.4	5.5	5.9
Other Organics	0.02		0.02	0.02		0.02	0.5	7.0	7.5
Ammonia							0.4		0.4
Lead							0.003		0.003
Total Atmospheric	7.0	73.5	80.5	7.0	75.7	82.7	137.5	688.5	826.0
Waterborne Wastes - lb									
Dissolved Solids (oil field brine)							80.9		80.9
Acid	2.0		2.0	2.0		2.0	0.2		0.2
Mital ion	0.5		0.5	0.5		0.5	0.1		0.1
Other	0.5		0.5	0.5		0.5	2.8		2.8
Total Waterborne	3.0		3.0	3.0		3.0	84.0		84.0

TABLE 38

FUEL FACTORS

(in metric units)

	Gasoline (1,000 ℓ)			Diesel (1,000 ℓ)			Fuel Oil Mobile Source (1,000ℓ)		
	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total
Energy - 10^9 j	5.5	34.8	40.3	5.5	38.7	44.2	5.5	41.8	47.3
Solid Wastes - kg	4.3		4.3	4.3		4.3	4.3		4.3
Atmospheric emissions - kg									
Particulates	0.5	1.3	1.8	0.5	1.6	2.1	0.5	2.8	3.3
Nitrogen Oxides	4.2	14.4	18.6	4.2	44.3	48.5	4.2	12.6	16.8
Hydrocarbons	6.5	12.3	18.8	6.5	4.4	10.9	6.5	0.6	7.1
Sulfur Oxides	3.8	0.7	4.5	3.8	3.2	7.0	3.8	36.2	40.0
Carbon Monoxide	1.4	123.4	124.8	1.4	27.0	28.4	1.4	15.6	17.0
Aldehydes	0.05	1.4	1.45	0.05	0.4	0.45	0.05	1.2	1.25
Other Organics	0.1	5.3	5.4	0.1	0.4	0.5	0.1		0.1
Ammonia	0.05		0.05	0.05		0.05	0.05		0.05
Lead	0.0004	0.4	0.4004	0.0004		0.0004	0.0004		0.0004
Total Atmospheric	16.6004	159.2	175.8004	16.6004	81.3	97.9004	16.6004	69.0	85.6004
Waterborne Wastes - kg									
Dissolved Solids (oil field brine)	9.3		9.3	9.3		9.3	9.3		9.3
Other	1.1		1.1	1.1		1.1	1.1		1.1
Total Waterborne	10.4		10.4	10.4		10.4	10.4		10.4

	(1,000 cu m) Natural Gas Internal Combustion			(1,000 cu m) Natural Gas Industrial Heating			(1,000 cu m) Natural Gas Utility Heating		
	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total
Energy - 10^9 j	2.1	38.4	40.5	2.1	38.4	40.5	2.1	38.4	40.5
Solid Wastes - kg									
Atmospheric emissions - kg									
Particulates	0.05		0.05	0.05	0.3	0.35	0.05	0.2	0.25
Nitrogen Oxides	5.7	96.1	101.8	5.7	3.4	9.1	5.7	9.6	15.3
Hydrocarbons	16.4	12.8	29.2	16.4	0.05	16.45	16.4	0.02	16.42
Sulfur Oxides	0.2		0.2	0.2		0.2	0.2		0.2
Carbon Monoxide	1.7	25.6	27.3	1.7	0.3	2.0	1.7	0.3	2.0
Aldehydes					0.03	0.03		0.02	0.02
Other Organics					0.08	0.08		0.05	0.05
Ammonia									
Lead									
Total Atmospheric	24.05	134.5	158.55	24.05	4.16	28.21	24.05	10.19	34.24
Waterborne Wastes - kg									
Dissolved Solids (oil field brine)	3.0		3.0	3.0		3.0	3.0		3.0
Other									
Total Waterborne	3.0		3.0	3.0		3.0	3.0		3.0

	(1,000 ℓ) Residual Oil Indust. Heating			(1,000 ℓ) Fuel Oil Utility Heating			(1,000 ℓ) Distillate Oil Industrial Heating		
	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total
Energy - 10^9 j	5.5	41.8	47.3	5.5	41.2	46.7	5.5	38.7	44.2
Solid Wastes - kg	4.3		4.3	4.3		4.3	4.3		4.3
Atmospheric emissions - kg									
Particulates	0.5	2.8	3.3	0.5	1.0	1.5	0.5	1.8	2.3
Nitrogen Oxides	4.2	8.6	12.8	4.2	12.6	16.8	4.2	8.6	12.8
Hydrocarbons	6.5	0.4	6.9	6.5	0.2	6.7	6.5	0.4	6.9
Sulfur Oxides	3.8	30.0	33.8	3.8	30.4	34.2	3.8	17.0	20.8
Carbon Monoxide	1.4	0.5	1.9	1.4	0.4	1.8	1.4	0.5	1.9
Aldehydes	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.2	0.25
Other Organics	0.1		0.1	0.1		0.1	0.1		0.1
Ammonia	0.05		0.05	0.05		0.05	0.05		0.05
Lead	0.0004		0.0004	0.0004		0.0004	0.0004		0.0004
Total Atmospheric	16.6004	42.4	59.0004	16.6004	44.7	61.3004	16.6004	28.5	45.1004
Waterborne Wastes - kg									
Dissolved Solids (oil field brine)	9.3		9.3	9.3		9.3	9.3		9.3
Acid									
Metal ions									
Other	1.1		1.1	1.1		1.1	1.1		1.1
Total Waterborne	10.4		10.4	10.4		10.4	10.4		10.4

	(1,000 ℓ) Coal Industrial Heat			Coal Utility Heat (1,000 kg)			Diesel Locomotive (1,000 ℓ)		
	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total	Pre-combustion	Combustion	Total
Energy - 10^9 j	0.47	30.5	31.0	0.45	30.5	31.0	5.5	38.7	44.2
Solid Wastes - kg	190.0	31.0	221.0	190.0	69.0	259.0	4.3		4.3
Atmospheric emissions - kg									
Particulates	2.0	21.0	23.0	2.0	11.0	13.0	0.5	3.0	3.5
Nitrogen Oxides	0.5	9.0	9.5	0.5	9.0	9.5	4.2	44.3	48.5
Hydrocarbons	0.5	0.5	1.0	0.5	0.2	0.7	6.5	11.3	17.8
Sulfur Oxides	1.5	42.0	43.5	1.5	55.0	56.5	3.8	6.8	10.6
Carbon Monoxide	2.5	1.0	3.5	2.5	0.5	3.0	1.4	15.6	17.0
Aldehydes	0.01	0.002	0.012	0.01	0.002	0.012	0.05	0.7	0.75
Other Organics	0.02		0.02	0.02		0.02	0.1	0.8	0.9
Ammonia							0.05		0.05
Lead							0.0004		0.0004
Total Atmospheric	7.03	73.502	80.532	7.03	75.702	82.732	16.6004	82.5	99.1004
Waterborne Wastes - kg									
Dissolved Solids (oil field brine)							9.3		9.3
Acid	2.0		2.0	2.0		2.0			
Metal ions	0.5		0.5	0.5		0.5			
Other	0.5		0.5	0.5		0.5	1.1		1.1
Total Waterborne	3.0		3.0	3.0		3.0	10.4		10.4

Source: Midwest Research Institute.

The total impacts associated with using a given quantity of a fuel are composed of: (1) precombustion impacts; and (2) combustion impacts. Precombustion impacts refer to the resource and environmental impacts associated with extracting, refining and shipping the fuel to its location of use. Combustion impacts represent the energy content of the fuel plus the environmental pollutants (atmospheric emissions) discharged upon combustion of the fuel. The sum of the precombustion and combustion impacts are identified as "secondary impacts," and represent the basic fuel impact factors associated with burning fossil fuels.

Table 38 contains the basic fuel factors for 12 energy resources. Tables 39 and 40 contain the precombustion impacts for natural gas and refined fuels.

TABLE 39

PRECOMBUSTION ENVIRONMENTAL IMPACTS RESULTING FROM PRODUCTION AND PROCESSING OF 1,000 CUBIC FEET OF NATURAL GAS

Impact category	Production	Processing	Total Precombustion
Energy - 10^6 Btu	0.021	0.035	0.056
Atmopsheric emissions - lb			
Particulates	0.002	0.001	0.003
Nitrogen oxides	0.119	0.238	0.357
Hydrocarbons	0.495	0.529	1.024
Sulfur oxides	0.010	0.002	0.012
Carbon monoxide	0.038	0.066	0.104
Total atmopsheric	0.66	0.84	1.50
Waterborne wastes - lb			
Dissolved solids (oil field brine)	0.184	0.007	0.19

Source: Midwest Research Institute.

TABLE 40

PRECOMBUSTION ENVIRONMENTAL IMPACTS RESULTING FROM PRODUCTION, REFINING AND DELIVERY OF 1,000 GALLONS OF LIQUID HYDROCARBON FUEL

Impact category	Production	Refining	Transportation	Total
Energy - 10^6 Btu	1.4	17.5	1.0	19.9
Solid wastes - lb				
Process	4.2	--	--	4.2
Fuel combustion	2.6	10.2	0.06	12.9
Mining	3.9	15.2	--	19.1
Total	10.7	25.4	0.06	36.2
Atmospheric emissions - lb				
Particulate	0.34	3.82	0.07	4.2
Nitrogen oxides	3.02	27.16	4.53	34.7
Hydrocarbon	10.83	42.16	1.34	54.3
Sulfur oxide	2.14	29.12	0.48	31.7
Carbon monoxide	1.63	7.75	1.92	11.3
Aldehydes	0.04	0.38	0.02	0.4
Other organics	0.01	0.43	0.01	0.5
Ammonia	--	0.42	--	0.4
Lead	--	--	0.003	0.0
Total atmospheric	18.0	111.2	8.4	137.6
Waterborne wastes - lb				
Dissolved solids (oil field brine)	77.33	3.23	0.31	80.9
Suspended solids	--	0.63	--	0.6
BOD	--	0.36	--	0.4
COD	--	1.12	--	1.1
Phenol	--	0.10	--	0.1
Sulfide	--	0.13	--	0.1
Oil	--	0.21	--	0.2
Acid	0.04	0.15	--	0.2
Metal ion	0.01	0.04	--	0.1
Total waterborne	77.4	6.0	0.3	84.0

Source: Midwest Research Institute.

2. Electric energy: The environmental impacts associated with use of electrical energy are summarized in Table I-40. The impacts were calculated on the basis of a composite kilowatt-hour (kw-hr). A composite kilowatt-hour is defined as 1 kilowatt-hour generated by the U.S. national average mix of fossil fuels and hydroelectric power. Data were obtained from the Edison Electric Institute for 1974 (Ref. 80).

Hydropower was assigned an energy equivalent of 3,413 Btu per kilowatt-hour and nuclear energy was assigned an energy equivalent of 21,330 Btu per kilowatt-hour. The amounts of fuel required are the total 1974 U.S. fuel requirements for electric utilities, divided by the total number of kilowatt-hours sold to customers. Impact factors from Table 38 were combined with the fuel quantities to arrive at the impact values in Table 41.

3. Transportation: Environmental impacts occur when goods are transported as a result of the consumption of fossil fuels to provide the necessary energy. In this study, the modes of transportation included are rail, truck, pipeline, and barge. These impacts were calculated by determining the kinds and amounts of fuels used by each mode on a national average basis. Impacts were then calculated for 1,000 ton-miles by mode.

a. Rail: A complete set of fuel consumption data indicates that diesel fuel accounted for 98 percent of the energy expended by railroads in 1968 (Ref. 9). We assumed that 100 percent of the energy was supplied by diesel fuel and that 5.63×10^{14} Btu of fuel were used. This fuel use resulted in 7.68×10^{11} ton-miles of transportation (Ref. 4). The corresponding fuel consumption was 5.25 gallons per 1,000 ton-miles. This value was combined with information in Table 38 to yield the impacts presented in Table 42.

b. Truck: In 1967, a total of 9.29×10^{9} miles were traveled by trucks engaged in intercity highway hauling. This resulted in 1.10×10^{11} ton-miles of transportation (Ref. 13). It is estimated that 35 percent of these miles were traveled by gasoline engine trucks while 65 percent were traveled by diesel fueled trucks (Ref. 9). National average fuel mileage data are not available, but a reasonable assumption based on actual experience is that this type of truck travel results in fuel consumption rates of about 5 miles per gallon for either type of fuel. Thus, 6.5×10^{8} gallons of gasoline and 1.20×10^{9} gallons of diesel fuel were used in 1967. From this, it was calculated that 5.9 gallons of gasoline and 10.9 gallons of diesel fuel were consumed per 1,000 ton-miles. Using data in Table I-37, impacts were calculated and reported in Table I-41.

TABLE 41

ENVIRONMENTAL IMPACTS RESULTING FROM GENERATION AND DELIVERY OF 1,000 COMPOSITE KILOWATT-HOURS OF ELECTRICITY, 1972

Impact category	Coal	Oil	Natural gas[a]	Other	Total
Quantity	0.23[a] ton	13.1[a] gal.	1,999[a] cu ft		
Percent of Btu	48.7	20.1	20.2	11.0	100
Impacts					
Energy - 10 6 Btu[a]	5.22	2.15	2.17	1.18	10.72
Solid wastes - lb					
Mining	83.6	-	-	-	83.6
Fuel combustion	30.4	0.3	-	-	30.7
Atmospheric emissions - lb					
Particulates	5.7	0.2	0.6		6.5
Nitrogen oxides	4.2	1.6	5.5		11.3
Hydrocarbons	0.3	0.6	3.5		4.4
Sulfur oxides	24.9	3.7	0.1		28.7
Carbon monoxide	1.3	0.1			1.4
Other	0.01	0.03	0.01		0.05
Total atmospheric	36.4	6.3	9.2	-	52.0
Waterborne wastes - lb					
Acid	0.96	0.06	0.58		1.6
Metal ion	0.24	0.01	0.11		0.4
Other	0.20	0.60	0.59		1.4
Total waterborne	1.4	0.7	1.3	-	3.4

Source: Midwest Research Institute.

[a] These values were derived from: Monthly Energy Review, Federal Energy Administration, August 1975.

TABLE 42

FUEL CONSUMPTION AND ENVIRONMENTAL IMPACTS RESULTING FROM 1,000 TON-MILES OF TRANSPORTATION BY EACH MODE

Impact category	Rail	Truck	Barge	Pipeline
Fuel				
Gasoline - gal.		5.9		
Diesel - gal.	5.3	10.9	1.4	
Fuel oil - gal.			6.1	
Natural gas - cu ft				670
Energy - 10^6 Btu	0.8	2.5	1.2	0.7
Solid wastes (fuel combustion) - lb	0.13	0.40	0.18	
Atmospheric emissions - lb				
Particulates	0.17	0.32	0.21	0.01
Nitrogen oxides	2.05	5.08	1.31	5.09
Hydrocarbon	0.72	1.73	0.41	1.47
Sulfur oxides	0.46	0.83	2.11	0.01
Carbon monoxide	0.45	8.66	1.17	1.41
Aldehydes	0.03	0.12	0.07	
Other organics	0.04	0.07	0.01	
Ammonia				
Lead		0.02		
Total atmospheric	3.9	16.8	5.3	8.0
Waterborne wastes - lb				
Dissolved solids (oil field brine)	0.394	1.260	0.562	0.147
COD	0.004	0.013	0.006	
Acid	0.001	0.003	0.001	
Metal ion		0.001		
Other	0.005	0.016	0.008	
Total waterborne	0.40	1.29	0.57	0.15

Source: Midwest Research Institute.

c. Barge: During 1966, barge traffic resulted in 5.0 x 10^{11} ton-miles of transportation (Ref. 5). Fuel consumption was 6.99 x 10^8 gallons of diesel fuel and 3.09 x 10^9 gallons of residual. Therefore, 1.4 gallons of diesel fuel and 6.1 gallons of residual were consumed per 1,000 ton-miles. Impacts were calculated and are listed in Table 42.

d. Crude oil and products pipeline: Sources in the pipeline industry report that, on the average, about 30 cubic feet of natural gas fuel are required to transport one barrel of oil 300 miles through a pipeline. This requirement translates to 30 cubic feet for 45 ton-miles, or 0.67 cubic feet of natural gas per ton-mile of crude petroleum transportation. This factor, combined with information from Table 38, gives the data necessary to calculate the impacts for 1,000 ton-miles of pipeline transportation. Pipeline transportation impacts for moving other types of liquids of interest in this study were assumed to be approximately the same as for crude oil.

According to the data of Table 42, transportation by truck has the greatest environmental impacts of the four transportation modes. This is a result of the relative inefficiency of the gasoline engine. Truck transportation ranks highest in every impact category. Computer analysis comparing the four transport modes shows that the impacts for trucks is more than double that of barge transportation, greater than triple that of rail transportation, and nearly five times higher than pipeline transport. Despite these rather high values for trucks, transportation per se is usually only a small percent (e.g., 10 percent) of the total impact of a particular product system.

B. Refillable Glass Bottles

1. Raw materials extracting and processing

a. Glass sand mining: Glass sand is the predominant raw material for glass manufacture. It comprises 53 percent by weight of the raw materials shown in Figure 26 and is the source of almost all of the silicon dioxide present in finished container glass. Silicon dioxide is the major chemical constituent of glass and amounts to approximately 70 percent by weight of the finished container glass.

Glass sand is a high purity quartz sand which usually contains less than 1 percent other minerals or foreign materials. These stringent purity restrictions prevent the use of most of the sand available in this country. However, sizable deposits of glass sand do exist in New Jersey in the form of unconsolidated sand banks, and as sandstones found in the Alleghenies and the Mississippi River Valley. In addition, there are smaller deposits of glass sand located in various other sections of the country.

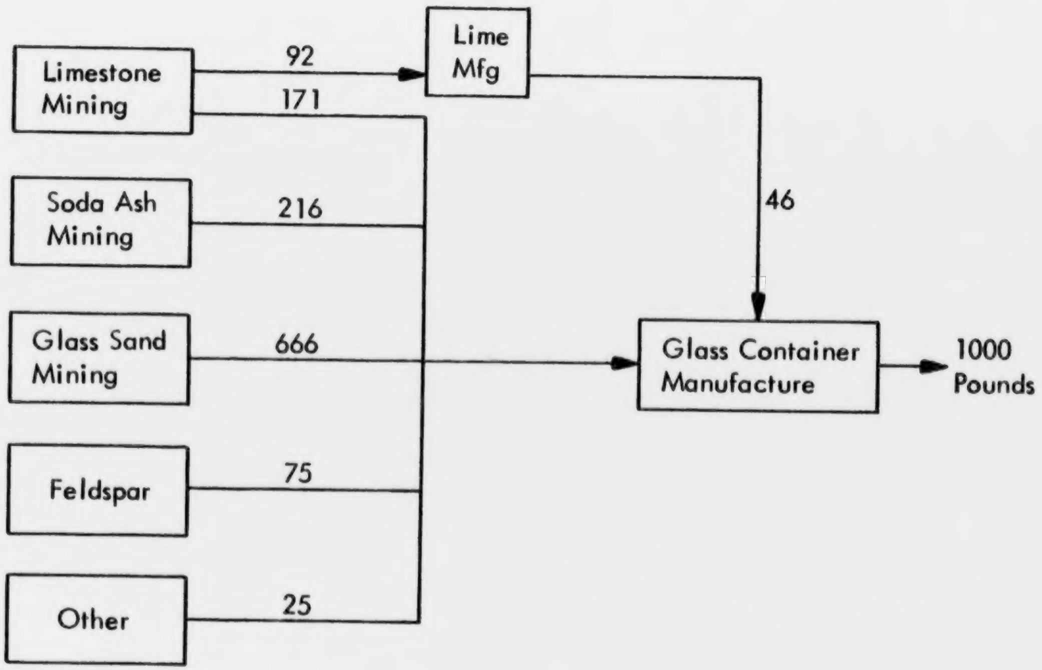
Limestone Mining
92
171
Lime Mfg
46
Soda Ash Mining
216
Glass Sand Mining
666
Glass Container Manufacture
1000 Pounds
Feldspar
75
Other
25

Figure 26. Raw materials requirements for glass container manufacture (in pounds).

The mining operations chosen depend on the nature of the deposit at each location. The mining operations range from simply scooping sand from a pit or bank and loading it into a truck, to quarrying hard sandstone in a fashion similar to the procedures used to extract limestone. In the latter event, extensive crushing, washing and screening may be necessary.

Data pertaining to the mining of 1,000 pounds of glass sand are shown in Table 43 along with the sources of each number.

TABLE 43

DATA FOR MINING OF 1,000 POUNDS GLASS SAND

Impact category	Value	Source
Energy		
Coal	5.8 lb	1
Distillate	0.155 gal.	
Residual	0.055 gal.	
Gas	216 cu ft	
Gasoline	0.038 gal.	
Electricity	6.95 kw-hr	
Water volume	900 gal.	2
Waterborne wastes		
Suspended solids	0.5 lb	17

b. Limestone mining: Limestone is used by the glass industry as a source of calcium oxide in glass furnace operations. The limestone is heated in the furnace so that carbon dioxide is released, leaving calcium oxide behind. Calcium oxides act as a chemical stabilizer in the finished glass product.

Limestone is quarried primarily from open pits. The most economical method of recovering the stone has been blasting, followed by mechanical crushing and screening. According to the Bureau of Mines, environmental problems are greater for crushed-stone producers than for any other mineral industry operation except sand and gravel (Ref. 18). The reason for this is that limestone typically is mined quite close to the ultimate consumer, which frequently dictates that the mining operation be near, or even within, heavily populated areas. Hence, environmental problems are accentuated because of high visibility.

The environmental consequences of limestone mining include: noise from heavy equipment and from blasting; dust from mining, crushing and screening; solid residues not properly disposed of; general unsightliness; and occasional contamination of streams. None of these problems is insurmountable, and many quarries are presently operated in an environmentally acceptable fashion.

Data concerning the quantifiable environmental impacts of limestone mining are summarized in Table 44. Even though the quarrying operations may be objectionable as a neighborhood problem, they produce relatively low impacts on a tonnage basis (partly because of the inherently high density of the stone). The major problem is dust, i.e., particulates. However, compared to the other operations in the glass container system, the impacts of limestone mining are quite small.

TABLE 44

DATA FOR MINING OF 1,000 POUNDS LIMESTONE

Impact category	Value	Source
Energy		1
Coal	0.12 lb	
Distillate	0.08 gal.	
Residual	0.065 gal.	
Natural gas	4.65 cu ft	
Gasoline	0.0245 gal.	
Electricity	1.0 kw-hr	
Water volume	45 gal.	2
Process atmospheric emissions		
Particulates	6.5 lb	6

c. Lime manufacture: Lime is produced by calcining limestone. Limestone (calcium carbonate) is heated in a kiln to a high temperature so that any water present is driven off and the carbonate is broken up by the evolution of carbon dioxide. The product remaining is lime (calcium oxide). Significant environmental impacts occur as a result of fuel combustion and material losses. For 1,000 pounds of lime produced, approximately 800 pounds of carbon dioxide is released. An additional 200 pounds of material impacts on the environment in the form of solid waste and as dust (particulate emission). The data are summarized in

Table 45. This table was derived from U.S. Census of Manufactures data for the year 1972, with the energy values adjusted downward to reflect energy conservation through 1980. Energy use was assumed to decline at a compound rate of 1.4 percent per year from the base year to 1980 (Ref. 10).

TABLE 45

DATA FOR MANUFACTURE OF 1,000 POUNDS LIME

Impact category	Value	Source
Virgin raw materials	4,000 lb	7
Energy		8,10
Coal	75.6 lb	
Distillate	0.0714 gal.	
Residual	0.32 gal.	
Natural gas	700 cu ft	
Gasoline	0.028 gal.	
Electricity	11.8 kw-hr	
Water	135 gal.	8
Solid wastes	182 lb	6,7
Process atmospheric emissions		
Particulates	16 lb	6,7

d. Natural soda ash mining: Soda ash, which is the common name for sodium carbonate, is used in glass manufacture as a fluxing agent. Under the temperature conditions of a glass furnace, the carbonate is converted to sodium oxide which lowers the melting and working temperature and decreases the viscosity of the melt. Sodium oxide is the second most abundant material in finished glass, constituting about 15 percent of the finished glass weight.

Soda ash is obtainable in either its natural form or in a manufactured form. The glass industry has utilized manufactured soda ash in the United States for most of this century. However, in the late 1950's, large beds of natural soda ash (trona) were discovered in Wyoming. It is also mined in California. Since the 1950's, trona has achieved considerable market penetration; until 1973, trona accounted for 38 percent of the soda ash used by the glass industry.

Since 1973, a combination of market, energy, and environmental pollution factors have acted together to force the closing of numerous synthetic soda ash plants, thus increasing the penetration of trona in the market. There is general agreement that in the near future, the manufacture of synthetic soda ash will practically cease in this country, and the glass industry will be using only trona as a source of soda ash. We estimate that by 1977, all of the soda ash used to manufacture glass will be trona.

Table 46 shows that natural soda ash mining produces relatively low environmental impacts compared to the other operations in glass manufacture. However, the substantially greater use of energy as compared to the other mined minerals leads to higher atmospheric emissions than experienced by other minerals' mining operations.

TABLE 46

DATA FOR MINING OF 1,000 POUNDS NATURAL SODA ASH (TRONA)

Impact category	Value	Source
Energy		
Natural gas	2,900 cu ft	3
Water volume	600 gal.	2
Mining wastes	60 lb	11
Process atmospheric emission		
Particulates	5 lb	17

e. Feldspar mining: Feldspar is an aluminum silicate mineral which is used in glass manufacture to obtain aluminum oxide. This oxide acts as a stabilizer and improves the stability and durability of the glass microstructure. It is added in small quantities and generally makes up less than 3 percent of the total glass weight. Alternative minerals to feldspar are nepheline, syenite and apatite. These minerals are sometimes used in glass manufacture. We have assumed that the impacts which result from using these minerals are similar to impacts incurred when using feldspar.

Feldspar is mined in 13 states, but North Carolina and California produce 65 percent of the nation's total. Hence, transportation expenses to bring feldspar to glass plants may be quite high. Feldspar is mined primarily by open pit quarry techniques. Usually drilling and blasting are required although this is not always so.

The data pertaining to the impacts associated with feldspar mining are in Table 47. The dominant impact is the considerable mining waste associated with feldspar mining. More solid waste is associated with this operation per ton of material than any other operation for glass manufacture. Also, there is a significant amount of air pollution, primarily dust produced by mining and crude mineral processing.

TABLE 47

DATA FOR MINING OF 1,000 POUNDS FELDSPAR

Impact category	Value	Source
Energy		1
Distillate	1.9 gal.	
Gas	30 cu ft	
Gasoline	0.0125 gal.	
Electricity	28 kw-hr	
Water volume	2,250 gal.	2
Mining wastes	2,300 lb	14
Atmospheric emissions		17
Particulates	7.5 lb	

f. Salt mining: Salt (sodium chloride) is obtained primarily by the following three methods (Ref. 63): (1) pumping water into salt deposits and recovering the salt as brine; (2) mining rock salt; and (3) solar evaporation of seawater.

The first method uses water to dissolve the salt and bring it to the surface. About 320 gallons of water will dissolve 1,000 pounds of salt. The saturated solution is removed from an adjacent well or by means of an annualar pipe. The brine contains sodium chloride, calcium chloride and magnesium chloride plus traces of hydrogen sulfide and ferrous ions. The purification required varies and depends on the purity of the deposits.

Rock salt is "mined" by blasting the mineral and removing the salt crystals. The crystals are crushed in the mine and then again at the surface. The remaining processes consist of grinding and screening operations. The produce is not as pure as salt from brine wells.

Seawater contains about 3.7 percent solids of which about 77.8 percent is sodium chloride. The water is evaporated to various degrees in several ponds. The evaporation steps serve to precipitate most of the compounds other than sodium chloride. After the final evaporation step, the salt solids are crushed and washed with salt brine to produce an industrial grade material. Additional steps can be incorporated to produce high purity salt.

Table 48 shows the data pertaining to mining 1,000 pounds of salt. The values are in most cases national averages and include impacts from each salt mining process.

The raw materials category shows that 1,026 pounds of mineral must be mined to ship 1,000 pounds of salt. The rock salt mining phase of the industry experiences its losses in the form of "fines," whereby some mines have as much as 20 percent waste. The water-brine type of mine will experience losses from water discharges. The average purity of salt deposits is around 98.5 percent.

2. Refillable glass container manufacture: Glass container manufacture is carried out in an integrated plant where raw materials are delivered and finished glass containers are shipped out. The raw materials are melted and refined in a glass furnace before being fed in a molten state to forming machines. These machines form and cool the glass container prior to the annealing step. After being annealed, they are further cooled and packed for shipment. Glass breakage occurs inside the plant as a result of handling or rejection of "off spec" containers. This broken glass (cullet) is a valuable raw material and is recycled to the glass furnace. Typically, the raw material batch will include 15 percent cullet from internal plant sources.

Glass is a three-dimensional random network of silicon and oxygen atoms with fluxes and stabilizers added. Thus, glass sand (silicon dioxide) is the primary raw material. Other important materials added include soda ash, lime or limestone and feldspar.

In the glass furnace, soda ash is converted to a sodium oxide, which serves as a fluxing agent. The fluxing agent alters melting and working temperatures of the "melt" by decreasing the viscosity of the raw materials. Limestone yields lime (calcium oxide) in the glass furnace. Calcium oxide and aluminum oxide from feldspar are stabilizers which add desirable characteristics such as chemical durability to the final product. Other additives are made in small amounts to add color and to

TABLE 48

DATA FOR MINING 1,000 POUNDS OF SALT

Impact category	Value	Source
Raw materials		
Salt mineral	1,026 lb	63
Explosives	0.28 lb	64
Ammonium nitrate	0.28 lb	64
Energy		37
Electric	4.25 kw-hr	
Fuel oil	0.059 gal.	
Gasoline	0.007 gal.	
Natural gas	84.0 scf	
Water volume	255.0 gal.	64
Mining solid wastes	15.0 lb	63
Mining atmospheric emissions		
Particulates	1.0 lb	63
Hydrogen sulfide (odorous sulfur)	0.0015 lb	63
Waterborne wastes		
Dissolved solids	10.0 lb	62,63
Transportation		37
Rail	500 ton-miles	

change refining characteristics for other purposes. Data pertaining to glass manufacture are given in Table 49.

TABLE 49

DATA FOR MANUFACTURE OF 1,000 POUNDS GLASS CONTAINERS

Impact category	Value	Source
Virgin raw materials		3
Sand	666 lb	
Limestone	263 lb	
Soda ash (natural)	216 lb	
Feldspar	75 lb	
Other	25 lb	
Packaging		
Corrugated	66 lb	8
Energy		3
Residual	1.8 gal.	
Gas	4,680 cu ft	
Electricity	125 kw-hr	
Water	250 gal.	3
Process solid waste	13 lb	3
Process atmospheric emissions		3
Particulates	1.0 lb	
Sulfur oxides	0.8 lb	
Waterborne wastes		3
Suspended solids	0.07 lb	

Source: Franklin Associates, Ltd., for MRI.

Glass container plants are quite clean from an environmental effluent point of view as compared to many types of industrial plants. This does not mean that glass plants are free of environmental effluents, but the effluents are generally minimal.*

The formation of glass requires that a considerable amount of heat be expended in melting the inorganic chemicals and in sustaining the temperatures at which the necessary chemical reactions and subsequent refining take place. However, the widespread use of natural gas in glass furnaces results in quite low atmospheric amissions for this sizable energy expenditure. (Natural gas produces minimal air emissions, but of course is in short supply as an energy resource.)

Glass milk containers are quite heavy when compared to other milk containers. They range in weight from 3.2 pounds for the gallon size, to one-half pound for the half pint size. These values are summarized in Table 50. The gallon size requires the least glass per 1,000 gallons of capacity as shown on the table. The half gallon size requires 1.3 times as much glass, and the half pint size requires 2.5 times as much glass as for the gallon size. Thus, much greater manufacturing impacts are incurred in producing smaller containers than larger ones for the same volume of milk delivered.

TABLE 50

WEIGHTS OF GLASS MILK CONTAINERS

Container size	Weight/ container (pound)	Containers/ thousand gallons milk	Weight/ thousand gallons milk	Ratio[a]
One gallon	3.2	1,000	3,200	1.0
Half gallon	2.03	2,000	4,060	1.3
Half pint	0.50	16,000	8,000	2.5

Source: Reference 19.

a/ Ratio of container weight to gallon container weight.

---

* However, any large industrial plant may "load" a local ecosystem even though its impact per ton of material is quite low. Thus, this factor must be considered even though the per unit impact is low; i.e., total units of output from a given site can be very important.

3. Container washing and filling processes: Glass bottles enter a dairy and are washed on automatic or semiautomatic machinery before being filled with fresh milk and cooled for shipment to the customer. The resource and environmental impact data for washing and filling of glass milk bottles are given in Table 51.

TABLE 51

WASHING AND FILLING GLASS MILK BOTTLES FOR DELIVERY OF 1,000 GALLONS MILK

Impact category	1,000 Gallon containers	2,000 Half gallon containers	16,000 Half pint containers	Source
Materials				3
New glass bottles,[a] lb	3,200/N	4,060/N	8,000/N	
Paperboard closures, lb	5.07	10.14	81.1	
Caustic, lb	2.0	2.0	2.0	
Hypochlorite, gal.	0.2	0.2	0.2	
Energy				3
Gas, cu ft	166.0	178.0	215.0	
Electricity, kw-hr	2.25	3.0	5.41	
Water, gal.	300.0	300.0	300.0	3
Solid waste				3,15,16
Sewage sludge, lb	3.4	3.4	3.4	
Water pollutants				3,15,16
BOD, lb	0.23	0.23	0.23	
Suspended solids, lb	0.35	0.35	0.35	
Alkalinity, lb	2.0	2.0	2.0	

---

[a] N represents the average trips per bottle being attained.

The dairy operation consists primarily of activities relating to receiving and processing of milk and milk products. However, this study is focused on impacts relating to alternate containers, so the data on Table 51 relate only to the dairy operations that are specifically related to milk containers.

The first category listed on Table 51 is the materials required to accomplish the filling of glass bottles to deliver 1,000 gallons of milk to the ultimate consumer. Most of the glass is part of the refillable bottle system, and so comes into the plant as used milk bottles which require washing. However, because of the losses of containers from the refillable bottle system, it is necessary to replace a certain portion of the bottles with new bottles. The weight of glass required is the weight of 1,000 gallon containers, divided by N, the average number of trips a container makes before it is broken or otherwise removed from the system. For example, if the average trippage is 20 trips per container, the average weight of new glass bottles required will be 160 pounds for gallon jugs, 203 pounds for half gallons, and 400 pounds for half pints.

To complete the filling operation, it is necessary to cap the bottle. It is assumed that a 2.3 gram paperboard cap is used for each gallon and half gallon bottle. This assumption is the same as that used for the refillable plastic bottle. The half pint containers were assigned a 0.65 gram closure.

The other materials listed are the chlorine and caustic required for washing and sanitizing the bottles. It is assumed that the use of these chemicals depends on the volume filled, not on bottle size. Personal interviews with dairies indicate that this is approximately correct.

The use of refillable glass containers for packaging milk affects energy use in the dairies in two ways. First, the glass requires significant energy to warm it to washing temperatures. Second, after washing, the bottles must be cooled to sufficiently low temperatures to keep milk fresh. Our data show that the energy for the actual washing of bottles requires 155 cubic feet of gas and 0.25 kilowatt-hour of electricity for washing 1,000 gallons volume milk containers. The additional energy requirements shown on Table 51 represent the natural gas requirements to raise the temperature of the glass an average of 100°F by using natural gas for heating water, and electricity required for refrigeration to cool the glass 100°F. However, it should be realized that the actual values experienced would vary widely, depending on outside temperatures and the degree to which the bottles are cooled by water.

The values on Table 51 which relate to solid waste and water pollutants are based on 1977 federal water pollution standards; calculated on the basis of disposal of 0.5 percent of milk filled, and dumping of caustic soda from the washer. It is assumed that most dairies will meet this standard by 1977.

4. Secondary packaging: The secondary packaging requirements for the refillable glass milk bottle system consist primarily of the corrugated packaging required to ship the bottles to the dairy. For all steps prior to this, materials are shipped in bulk. At all steps subsequent to this, the bottle is carried in a plastic (or wood) case which has an indeterminate, but high trippage rate. Thus, the only quantifiable consumption of packaging materials is 66 pounds of corrugated packaging per 1,000 pounds of glass bottles.

5. Transportation profile: The transportation requirements for the refillable glass bottle manufacturing system resulting in the delivery of 1,000 pounds of glass containers to a dairy are summarized in Table 52. These values are derived from References 1 and 9. Three factors affect the transportation energy requirements: (1) the energy efficiency of the mode of transport; (2) the amount of material shipped; and (3) the distance traveled. Shipment of the empty containers requires the most energy, 93 ton-miles by truck and 25 ton-miles by rail. The extent of transportation per 1,000 gallons of milk depends on the amount of glass required, which in turn depends on the trip rate.

TABLE 52

SYSTEM TRANSPORTATION FOR MANUFACTURE OF 1,000 POUNDS GLASS CONTAINERS
(Ton-miles)

System component	Rail	Truck	Barge
Glass sand - 666 lb	30	9	1
Soda ash - 216 lb	70	-	-
Limestone - 263 lb	1	5	-
Feldspar - 75 lb	19	-	-
Lime - 46 lb	3	1	-
Glass containers - 1,000 lb	25	93	1
Corrugated containers - 66 lb	3	5	-

Source: Midwest Research Institute.

Data concerning the delivery of filled containers are shown in Table 53. Transportation values were derived by assuming that store delivery results in a 60-mile round trip, by trucks carrying an average load of 647 cases, which consists of bottles and 4-pound carrying cases, as well as the milk. A fuel efficiency of 5 miles per gallon was assumed. Home delivery was based on the assumption that in addition to a 60-mile round trip, the delivery truck would deliver its load of 175 cases at the rate of one case per 0.1 mile, or 17.5 miles.

TABLE 53

DELIVERY OF 1,000 GALLONS MILK IN THREE SIZES OF GLASS CONTAINERS

	One Gallon	Half gallon	Half pint
Store or institutional Delivery			
Gasoline - gal.	2.3	2.5	3.2
Diesel - gal.	2.5	2.5	3.2
Home delivery			
Gasoline - gal.	22.0	24.0	-

Source: Midwest Research Institute.

The weight analysis data in Table 54 show that the glass container accounts for a large percentage (25.0 to 45.4) of the total shipping weight.

TABLE 54

WEIGHT ANALYSIS FOR DELIVERING 1,000 GALLONS OF MILK IN THE REFILLABLE GLASS BOTTLE SYSTEMS

	One gallon		Half gallon		Half pint	
Component	lb	%	lb	%	lb	%
Container	3,200	25.0	4,061	29.7	8,007	45.4
Closure	5	0.03	10	0.07	23	0.1
Cases	1,000	7.8	1,000	7.3	1,000	5.7
Milk	8,600	67.2	8,600	70.0	8,600	48.8
	12,805	100.0	13,671	100.0	17,630	100.0

Source: Midwest Research Institute.

6. Postconsumer solid waste and recycling: Once milk bottles are rejected from the filling line, broken or discarded, they may be either disposed of or recycled. If disposed of, the bottles or broken bottle pieces must be hauled to a landfill. Even if incinerated, the glass bottle residue must be disposed of in a landfill eventually.

The volume occupied by a glass jug in solid waste consists of the volume of the glass itself, plus the volume of the void space inside unbroken or partially broken containers. Based on data from municipal engineers, we have assumed that 65 percent of the original volume of a glass jug remains as void space in compactor trucks and landfills (Ref. 20). Thus, the volume of the glass added to the void space yields an average volume of 33 cubic feet per 1,000 pounds of gallon containers (see Table 55). Assuming a fuel expenditure of 0.5 gallon gasoline per cubic yard (0.0185 gallons per cubic foot) for solid waste disposal yields a value of 0.61 gallon of gasoline required per 1,000 pounds of glass containers (Ref. 21).

If a dairy is located close to a glass plant, waste glass would be sold as cullet for recycling. The energy and environmental impact profiles of recycling glass results in small (10 percent) improvements of overall glass system profiles (Ref. 21). The primary impact is the reduction in solid waste generation, which is already quite small for refillable glass anyway. However, only a small percentage of the scrap milk bottle glass (cullet) is generated close enough to glass plants to be utilized as cullet. Thus, it can be concluded that the effect of glass recycling is not an important consideration for milk bottle systems.

C. Refillable Plastic Bottle

1. Raw materials extracting and processing

a. Production of crude oil and natural gas: A producing well is classified as a gas or oil well, based on the ratio of the oil to gas production. An "oil" well will typically produce at least one barrel of oil to each 100,000 cubic feet of natural gas; the "gas" well has a lower crude-to-gas ratio. However, in the USA, most of the gas is captured and sold whether it comes from a gas well or an oil well.

Field processing is required to separate the oil, gas, and water. The natural gas then generally follows three routes. The gas can be flared. Some gas can be returned to the underground formation to assist in future production. The gas can be sent to a natural gas processing plant.

TABLE 55

IMPACTS OF SOLID WASTE DISPOSAL

Material	Nominal volume of 1,000 pounds of one gallon containers		Volume occupied by 1,000 pound container material	Void space Void space in waste stream[a]		Total volume in waste	Gasoline[b]
	(gallon)	(cu ft)	(cu ft)	(percent)	(cu ft)	(cu ft)	(gallon)
Glass	312	41.7	6	65	27.1	33	0.61

Source: Midwest Research Institute

[a] See text for explanation.

[b] Assuming 0.0185 gal./cu ft waste disposal. See Reference 21.

Crude oil is sent first to water separators, and then to oil-gas separators. The resulting crude is sent to storage tanks and then to the refinery.

A generalized flow diagram for the production of oil and natural gas is given in Figure 27.

Detailed information is scarce concerning the ways in which drilling fluids, drilling muds, well cuttings, and well treatment chemicals may contribute to pollution. Studies have been made of well blowout and mixing of fresh water aquifers and oil-bearing sands. Several publications are available on the subject of oil field brine disposal by subsurface injection (Ref. 27).

The data below are the approximate amounts of acids used in the United States in 1 year for oil and gas well treatment (Ref. 62).

ACIDS USED FOR WELL TREATMENT

Acid	Gallons per Year	Gallons/barrel crude produced
Hydrochloric	8.7×10^7	26.4×10^{-3}
Formic	2.0×10^6	6.0×10^{-4}
Acetic	1.0×10^6	3.0×10^{-4}

Also, approximately 30×10^5 pounds of inhibitor and 37×10^5 pounds of additives are used per year in well treatment. The total domestic crude production in 1972 was 3,234,600,000 barrels. The quantity of inhibitors per barrel of crude was 9.3×10^{-4} pounds; the quantity of additives, 11.4×10^{-4} pounds per barrel. Since these products are injected into the subsurface reservoir, the amount of pollution to fresh water acquifers is probably very small. The drilling muds used prior to production are usually expensive and, therefore, merit special handling to prevent excessive losses. However, most spent muds are left in open slush pits to permit evaporation of liquids. Most pits are earth filled when evaporation is complete. Some remain in limited service to contain the effluents from well servicing.

Several sources of pollution resulting from oil field operations are:

* Well blowout - resulting in surface and subsurface contamination.

- Dumping of oil-based drilling muds, oil-soaked cuttings and treatment chemicals.

- Crude oil escape from pipeline leaks, overflow of storage vessels and rupture of storage and transport vessels.

- Discharge of bottom sediment from storage vessels.

- Subsurface disposal of brine into a formation which would permit migration of the brine into an area, resulting in pollution of fresh water or contributing toward other natural disasters.

- Escape of natural gas containing hydrogen sulfide could pollute fresh water supplies and local atmosphere.

Crude losses from production are estimated to be 0.13 percent based on information in the 1971 Minerals Yearbook. This loss has been accounted for by allocation to the energy of material resource and to environmental pollutants. The energy content of the crude oil was 19,500 Btu per pound. This assumes an average API gravity of 35 which is equivalent to a weight of 297 pounds per barrel of crude oil. Therefore, the total energy of material resource assigned to the production of 1,000 pounds of crude oil is 19,525,350 Btu (19,500,000 Btu + 25,350 Btu for crude losses in production). The process energy requirements were taken from the 1972 Census of Mineral Industries.

Natural gas losses were derived from 1971 and 1972 census data. The losses are estimated to be: (1) 0.36 percent from vents; (2) 0.36 percent from flares; (3) 1.69 percent in lease operations; and (4) 1.4 percent in transmission to the consumer, for a total loss of 3.81 percent.

In the production of 1,000 pounds of natural gas, this loss has been charged as 853,109 Btu (38.1 pounds x 0.046 cubic feet x 1,030 Btu per cubic feet) of material resource energy and 25.88 pounds of atmospheric emissions. (Crude production was charged with 8.62 pounds of atmospheric emissions since about 25 percent of the natural gas produced comes from oil wells.) The 0.36 percent burned in flares was not included in the atmospheric emissions. The total energy of material resource assigned to natural gas production is 23,244,109 Btu (22,391,000 Btu for 1,000 pounds of natural gas + 853,109 Btu for the 38.1 pounds of natural gas lost in production).

The principal waterborne wastes in oil and gas production are dissolved solids and oils. Approximately 2.5 barrels of brine are produced for each barrel of crude extracted. The brine contains about 32 pounds of dissolved solids (mostly chlorides) per barrel, and 0.59

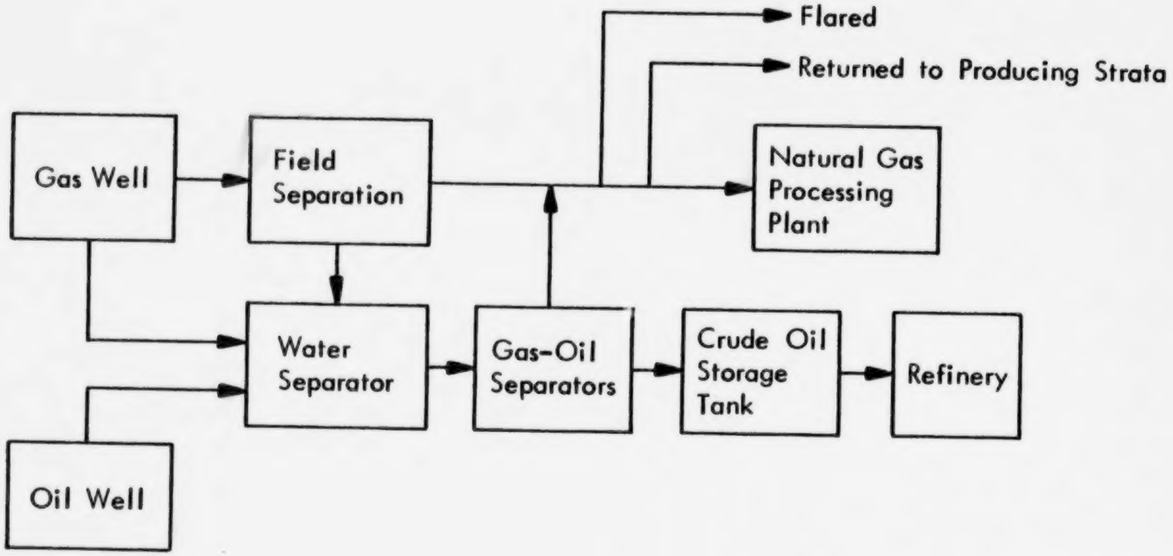
Flared
Returned to Producing Strata
Gas Well
Field Separation
Natural Gas Processing Plant
Water Separator
Gas-Oil Separators
Crude Oil Storage Tank
Refinery
Oil Well

Figure 27. Flow diagram for crude oil and natural gas production.

pounds of oils per barrel. Industry sources have estimated that approximately 10 percent of the brine enters streams, rivers, etc., while 90 percent is disposed of by methods which do not pollute water resources. Brine disposal methods include evaporation ponds, subsurface injection, and brine water treatment systems.

The 0.25 barrels of brine (containing 8 pounds of dissolved solids and 0.147 pounds of oils) which enter waterways contribute 6.0 pounds of dissolved solids and 0.11 pounds of oils to the production of 1,000 pounds of crude (3.367 barrels), and 2 pounds of dissolved solids and 0.037 pounds of oil to the production of 1,000 pounds of natural gas (75 percent allocated to crude production and 25 percent to natural production).

Table 56 contains the raw impact data for the production of 1,000 pounds of crude oil. Table I-56 contains the primary (raw) data for natural gas production. The energy content of these hydrocarbon products appears in the table. Crude oil and natural gas inputs are counted as their energy equivalents rather than pounds of raw materials.

b. Natural gas liquids processing: Light straight chain hydrocarbons are normal products of a gas processing plant. The plant uses compression, refrigeration and oil absorption to extract these products. First, the heavy hydrocarbons are removed. The remaining components are extracted and kept under controlled conditions until transported in high pressure pipelines, insulated railcars, or ships and barges. The primary wasted residues come from the natural gas stream as volatile hydrocarbons which leak into the atmosphere. Figure 28 shows a diagram of a natural gas processing plant.

Table 58 contains a summary of production impacts. The process energy values were obtained from the 1972 Census of Minerals Industries. The amount of natural gas processed was 18,530.8 x 10^9 cubic feet. The total gas used as fuel was 632.1 x 10^9 cubic feet, or 3.41 percent of throughput. This represents 742 cubic feet per 1,000 pounds of natural gas processed or 753 cubic feet per 1,000 pounds of natural gas liquids (allowing for 1.5 percent loss and also by-product credit for the residue gas). The 1971 Minerals Yearbook shows a loss of 0.36 percent (0.15 lost in flaring or venting + 0.21 percent unaccounted for) in NGL production. Industry sources report that losses in gas processing plants range between 1 and 2 percent. In this report, the total losses (processing, storage, and transportation) are estimated to be 1.5 percent.

With reference to atmospheric emissions, the sulfur oxides emitted from natural gas processing plants in 1971 was 1,036,000 metric tons or 2.62 pounds per 1,000 pounds of natural gas liquids produced (with by-product credit). Hydrocarbon emissions are estimated to be 10.0 pounds per 1,000 pounds of natural gas liquids.

TABLE 56

DATA FOR PRODUCTION OF 1,000 POUNDS OF CRUDE OIL

Impact category	Value	Sources
Energy of material resource	19.525 million Btu	37
Raw materials		37,58
Material process additions (chemicals 0.29, cement 1.0, muds 0.59)	1.88 lb	
Energy		
Electric	6.18 kw-hr	37,64
Residual oil	0.47 gal.	
Gasoline	0.02 gal.	
Natural gas internal combustion	287.2 cu ft	
Water volume	72.0 gal.	37
Solid wastes	0.60 lb	37
Process atmospheric emissions		37
Hydrocarbons	8.62 lb	
Waterborne wastes		27,32,37
Dissolved solids	6.0 lb	
Oil and grease	0.11 lb	
Transportation		37
Barge	28.0 ton-miles	
Truck	10.0 ton-miles	
Pipeline	110.0 ton-miles	

---

a/ 1,001.3 lb oil x 19,500 Btu/lb = 19.525 million Btu (includes 1.3 lb for losses).

TABLE 57

DATA FOR PRODUCTION OF 1,000 POUNDS OF NATURAL GAS

Impact category	Value	Source
Energy of material resource	23.244 million Btu[a]	37,81
Energy		37,64
Electric	6.18 kw-hr	
Fuel oil	0.1 gal.	
Gasoline	0.02 gal.	
Natural gas internal combustion	541.2 cu ft	
Water volume	29.0 gal.	33
Process atmospheric emissions		
Hydrocarbons	25.88 lb	28,37,64
Waterborne wastes		27,32,82
Dissolved solids	2.0	
Oil and grease		

---

[a] 1,038.1 lb NG x 0.46 lb/cu ft x 1,030 Btu/cu ft = 23.244 million Btu includes 38.1 lb losses.

TABLE 58

DATA FOR PRODUCTION PROCESSING 1,000 POUNDS OF NATURAL GAS LIQUIDS

Impact category	Value	Source
Energy		37,64
Electric	1.64 kw-hr	
Natural gas	753.0 scf	
Water volume	280.0 gal.	37
Process atmospheric emissions		37,64,83
Hydrocarbons	10.0 lb	
SOX	2.62 lb	
Transportation		37
Rail	42.0 ton-miles	
Truck	14.0 ton-miles	
Barge	14.0 ton-miles	
Pipeline	70.0 ton-miles	

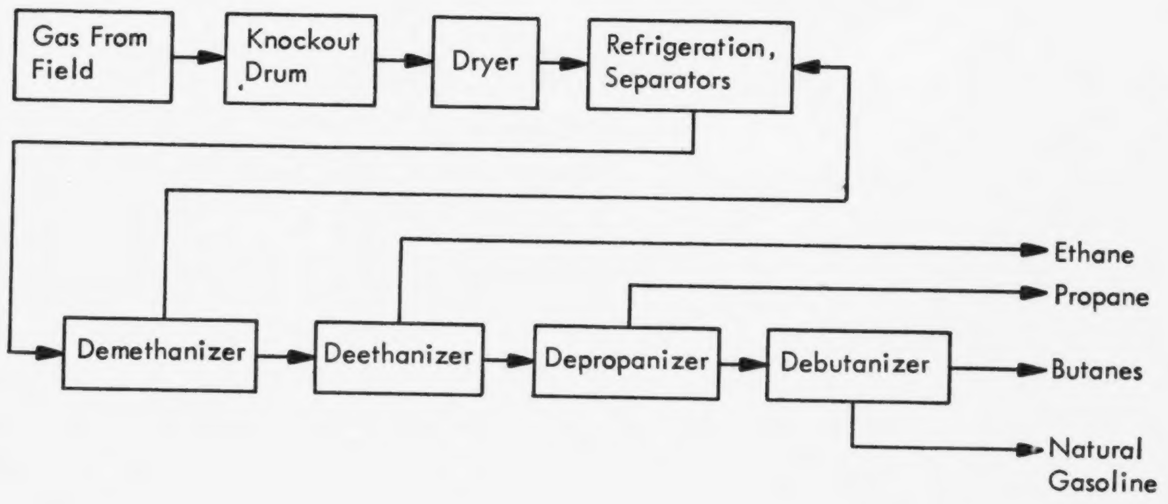
Gas From Field
Knockout Drum
Dryer
Refrigeration, Separators
Demethanizer
Deethanizer
Depropanizer
Debutanizer
Ethane
Propane
Butanes
Natural Gasoline

Figure 28. Flow diagram for a natural gas processing plant.

c. Petroleum distillation and hydrotreating: In the process used for crude oil distillation, the crude oil enters the distillation unit through a heat exchanger and proceeds through a desalter for removal of salt, sediment, and water. The treated crude then flows through additional heaters and into the fractionation unit (Ref. 54).

The naphtha "cut" is assumed to flow from the fractionation unit to a desulfurization process. The feed is preheated and reacted over a catalyst at 730° to 760°F to effect sulfur removal (Ref. 54). This process does not require an external source of hydrogen.

The impacts for distillation and hydrotreating are combined to give the raw impacts for producing 1,000 pounds of naphtha (Table 59).

d. Ethylene manufacture and profile analysis: The primary processes used for manufacturing ethylene are ethane and propane pyrolysis, naphtha cracking, and gas oil cracking. Presently, the pyrolysis of light gases accounts for 75 percent of the ethylene produced.

Figure 29 shows a flow diagram for the manufacture of ethylene. The hydrocarbon feedstock enters the cracking unit where decomposition occurs under the influence of heat and pressure. In the transition reaction that follows, ethylene and by-products are formed. When ethane is the principal feedstock, the final product distribution shows 80 percent ethylene and 20 percent by-products. For propane and naphtha feeds, ethylene represents 44 percent and 34 percent of the total reaction products (Hydrocarbon Processing, February 1974). Therefore, with the present feedstock mix (75 percent ethane/propane, 75 percent heavier feeds), ethylene represents about 60 percent of the total reaction products (assuming the light gas feed represents 62 percent ethane and 38 percent propane).

After cracking the feedstock the products are sent through heat exchangers for the recovery of furnace heat. The Btu recovery for ethane, propane, and naphtha feeds can approximate 2,100, 3,300 and 4,000 Btu, respectively, per pound of ethylene produced. After heat exchange, the reaction products are purified and fractionated into methane, ethylene propylene, etc.

The energy requirements for ethylene manufacture will depend upon the type of fuel used and the amount of heat recovery experienced. Based on Reference 21, the total process energy for manufacturing ethylene and coproducts in 1973 was 382.3×10^9 Btu. With an ethylene production in 1973 of 23×10^9 pounds, and assuming 60 percent of the total energy for ethylene and coproducts manufacture was used in the ethylene manufacture, the energy used to manufacture 1 pound of ethylene is 9,973 Btu. (As stated, ethylene represents about 60 percent of the products coming from an ethylene manufacturing process.) This agrees closely

TABLE 59

DATA FOR DISTILLATION AND HYDROTREATING 1,000 POUNDS OF PETROLEUM

Impact category	Value	Source
Raw materials		
Additions	1.0 lb	37
Energy		54
Electric	10.0 kw-hr	
Natural gas	543 cu ft	
Water (wastewater volume)	200 gal.	37,54
Solid wastes, process	3.5 lb	37
Atmospheric emissions, process		
Hydrocarbons	0.43 lb	52,53
Sulfur oxides	0.30 lb	31,35
Waterborne wastes		33
BOD	0.014 lb	
COD	0.071 lb	
TSS	0.0097 lb	
Oil and grease	0.004 lb	
Phenolic compounds	0.0001 lb	
Ammonia (N)	0.0013 lb	
Sulfides	0.0001 lb	
Chromium	0.0002 lb	

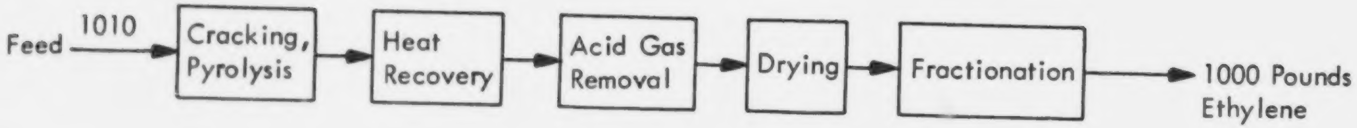
Feed
1010
Cracking, Pyrolysis
Heat Recovery
Acid Gas Removal
Drying
Fractionation
1000 Pounds Ethylene

Figure 29. Flow diagram for manufacture of ethylene (in pounds).

with the value stated in the article for ethylene manufacture corrected for by-products. Based on Reference 20, the energy requirement for manufacturing ethylene from naphtha is about 8,700 Btu per pound. Reference 24 indicates that ethylene can be manufactured from ethane with an energy requirement of approximately 3,000 Btu per pound. Confidential sources report that energy values of 5,000 to 7,500 Btu per pound of ethylene are representative of many ethylene plants. Reference 34 gives an excellent account of ethylene manufacture. This report shows that the fuel requirements for ethylene manufacture vary from 7,410 (from ethane) to 11,400 Btu per pound (from gas oil). For this report, the manufacture of ethylene has been charged with the following energy sources per 1,000 pounds of ethylene in 1975: electric = 77 kilowatt-hour and natural gas = 6,800 cubic feet. These values represent 11,200 Btu per pound of ethylene manufactured from naphtha and 7,200 Btu per pound for ethylene manufactured from ethane or propane, resulting in a national average of 8,200 Btu per pound of ethylene (75 percent ethane/propane pyrolysis and 25 percent naphtha cracking).

The raw impacts for producing 1,000 pounds of ethylene are shown in Table 60. The hydrocarbon feed requirements in the production process are approximately 1,010 pounds of feed per 1,000 pounds of ethylene.

The primary use of water in the cracking process is for dilution steam requirements and for quench waters required in the cooling and primary separation of the cracked gases. The major wastewater sources are the quench tower effluents and acid gas scrubber effluents. A common practice is to send the wastewater through a steam condensate stripper to remove hydrocarbons. The effluent water from the stripper can be reused. Wastewater volume is 355 gallons per 1,000 pounds of ethylene. The EPA 1977 effluent limitations are 0.058 pounds BOD and 0.088 pound TSS per 1,000 pounds of ethylene. Atmospheric emissions are reported to be 0.79 pound per 1,000 pounds of product.

The energy requirement for pollution control is 5.23 kilowatt-hour per 1,000 pounds of ethylene, or about 0.7 percent of the total energy requirements.

Table 61 contains the impacts of the ethylene system from raw materials extraction through the ethylene manufacturing step. The total energy requirement for the ethylene profile is 32.51 million Btu. The ethylene manufacturing step accounts for only 8.21 million Btu, or 25.3 percent of the total system energy. The energy of material resource accounts for 70.3 percent of the total energy. The natural gas production step has the highest impacts in the energy, atmospheric emissions, and waterborne waste categories.

TABLE 60

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF ETHYLENE

Impact category	Value	Source
Raw materials		
Process additions (1,071 lb hydrocarbon fuel)	5.0 lb	37,84
Energy		
Electric	77.23 kw-hr	37,45,84,85,86
Natural gas	6,800 cu ft	
Wastewater volume	335 gal.	44
Solid waste	18.0 lb	87
Atmospheric emission		88
Particulates	0.01 lb	
Sulfur oxides	0.09 lb	
Carbon monoxide	0.01 lb	
Hydrocarbons	0.67 lb	
Nitrogen oxides	0.01 lb	
Waterborne wastes		44
BOD	0.058 lb	
Suspended solids	0.088 lb	

TABLE 61

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS

1000 LB OF ETHYLENE SYSTEM

INPUTS TO SYSTEMS

NAME	UNITS	NAT GAS PROD 769 LB	NAT GAS PROCESS 758 LB	CRUDE OIL PROD 255 LB	CRUDE OIL DIST HYDROTRT 252 LB	ETHYLENE MFG 1000 LB	TOTALS
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.026	.003	5.002	.005	.166	5.202
ENERGY SOURCE NAT GAS	MILL BTU	18.337	.622	.083	.154	7.552	26.749
ENERGY SOURCE COAL	MILL BTU	.025	.006	.008	.013	.403	.456
ENERGY SOURCE MISC	MILL BTU	.006	.001	.002	.003	.091	.103
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	.479	.252	5.000	5.732
ENERGY PROCESS	MIL BTU	.051	.633	.111	.176	8.213	9.184
ENERGY TRANSPORT	MIL BTU	.467	0.000	.005	0.000	0.000	.472
ENERGY OF MATL RESOURCE	MIL BTU	17.875	0.000	4.979	0.000	0.000	22.854
WATER VOLUME	THOU GAL	.031	.223	.021	.053	.491	.819

OUTPUTS FROM SYSTEMS

NAME	UNITS	NAT GAS PROD 769 LB	NAT GAS PROCESS 758 LB	CRUDE OIL PROD 255 LB	CRUDE OIL DIST HYDROTRT 252 LB	ETHYLENE MFG 1000 LB	TOTALS
SOLID WASTES PROCESS	POUND	0.000	0.000	.153	.252	18.000	18.405
SOLID WASTES FUEL COMB	POUND	.149	.038	.053	.078	2.371	2.689
SOLID WASTES MINING	POUND	.397	.104	.132	.211	6.456	7.300
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	.034	.010	.013	.019	.655	.731
ATMOS NITROGEN OXIDES	POUND	2.712	3.640	.498	.107	4.765	11.723
ATMOS HYDROCARBONS	POUND	20.689	8.621	2.346	.260	7.993	39.910
ATMOS SULFUR OXIDES	POUND	.168	2.027	.071	.150	2.388	4.804
ATMOS CARBON MONOXIDE	POUND	.743	.974	.137	.021	.961	2.836
ATMOS ALDEHYDES	POUND	.001	.000	.001	.000	.015	.017
ATMOS OTHER ORGANICS	POUND	.001	.000	.000	.001	.036	.038
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	0.000	.000
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	0.000	0.000	.000
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	1.627	.109	1.567	.028	1.340	4.671
WATERBORNE BOD	POUND	.000	.000	.000	.004	.058	.062
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000
WATERBORNE OIL	POUND	.028	.000	.028	.001	.000	.058
WATERBORNE COD	POUND	.000	.000	.000	.018	.000	.019
WATERBORNE SUSP SOLIDS	POUND	.000	.000	.000	.002	.088	.091
WATERBORNE ACID	POUND	.008	.002	.003	.004	.124	.140
WATERBORNE METAL ION	POUND	.002	.000	.001	.001	.031	.035
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	.000	0.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000

SUMMARY OF ENVIRONMENTAL IMPACTS

NAME	UNITS	NAT GAS PROD 769 LB	NAT GAS PROCESS 758 LB	CRUDE OIL PROD 255 LB	CRUDE OIL DIST HYDROTRT 252 LB	ETHYLENE MFG 1000 LB	TOTALS
RAW MATERIALS	POUNDS	0.000	0.000	.479	.252	5.000	5.732
ENERGY	MIL BTU	18.393	.633	5.095	.176	8.213	32.510
WATER	THOU GAL	.031	.223	.021	.053	.491	.819
INDUSTRIAL SOLID WASTES	CUBIC FT	.007	.002	.005	.007	.362	.383
ATM EMMISSIONS	POUNDS	24.348	15.272	3.067	.558	16.814	60.059
WATERBORNE WASTES	POUNDS	1.665	.112	1.599	.058	1.641	5.075
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MIL BTU	.026	.003	5.002	.005	.166	5.202
ENERGY SOURCE NAT GAS	MIL BTU	18.337	.622	.083	.154	7.552	26.749
ENERGY SOURCE COAL	MIL BTU	.025	.006	.008	.013	.403	.456
ENERGY SOURCE NUCL HYPWR	MIL BTU	.006	.001	.002	.003	.091	.103
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000

INDEX OF ENVIRONMENTAL IMPACTS

NAME	STANDARD VALUES	NAT GAS PROD 769 LB	NAT GAS PROCESS 758 LB	CRUDE OIL PROD 255 LB	CRUDE OIL DIST HYDROTRT 252 LB	ETHYLENE MFG 1000 LB	TOTALS
RAW MATERIALS	5.732	0.0	0.0	8.4	4.4	87.2	100.0
ENERGY	32.510	56.6	1.9	15.7	.5	25.3	100.0
WATER	.819	3.8	27.2	2.6	6.5	59.9	100.0
INDUSTRIAL SOLID WASTES	.383	1.9	.5	1.2	1.9	94.5	100.0
ATM EMMISSIONS	60.059	40.5	25.4	5.1	.9	28.0	100.0
WATERBORNE WASTES	5.075	32.8	2.2	31.5	1.1	32.3	100.0
POST-CONSUMER SOL WASTE	0.000	0.0	0.0	0.0	0.0	0.0	0.0
ENERGY SOURCE PETROLEUM	5.202	.5	.1	96.2	.1	3.2	100.0
ENERGY SOURCE NAT GAS	26.749	68.6	2.3	.3	.6	28.2	100.0
ENERGY SOURCE COAL	.456	5.4	1.4	1.8	2.9	88.4	100.0
ENERGY SOURCE NUCL HYPWR	.103	5.4	1.4	1.8	2.9	88.4	100.0
ENERGY SOURCE WOOD WASTE	0.000	0.0	0.0	0.0	0.0	0.0	0.0

Figure 30 shows a flow diagram for the profile of 1,000 pounds of ethylene production. The present national average feed mix is 75 percent light gases and 25 percent heavy feeds (gas oil, naphtha, etc.).

e. High density polyethylene resin manufacture: In a typical process for the production of high density polyethylene (HDPE), ethylene feedstock is combined with solvents and co-monomers and fed to a tubular reactor containing catalyst and other additives. Reaction conditions will approximate 120° to 195°F and 425 psig. The reactor products are depressurized in a steam stripper where the unreacted materials are separated from the polymer. The polymer goes through a centrifugation step and final drying in an air fluidized bed dryer. The polymer is then extruded and pelletized.

Most of the process water used in the catalyst and polymer separation areas becomes wastewater containing small quantities of dissolved hydrocarbons.

The raw impact values for 1,000 pounds of HDPE are shown in Table 62. Actual plant data were obtained for the raw materials and energy values.

Members of the Society of the Plastics Industries, Inc., also provided information on energy requirements and environmental impacts. The waterborne wastes values were taken from an EPA development document for synthetic materials (Ref. 47).

2. Refillable plastic container manufacture: The refillable plastic container is manufactured from high density polyethylene. The HDPE resin is fed to the blow-molding machine (Figure 31) where the resin is melted and formed into a finished container. Typical production rates are 156 bottles per hour for the gallon size and 163 bottles per hour for the half gallon size.[a] After fabrication the containers are transferred by a belt conveyor through an annealing oven maintained at 195° to 205°F. The residence time in the oven is 30 minutes per container. The natural gas consumption of the oven is estimated to be 112,500 Btu per hour (109 cubic feet per hour). The annealing process is assumed to proceed at the same rate as bottle production at the blow-molding machines.

In the manufacturing process, 98 percent of the scrap resin is recycled, with the remaining 2 percent sent to municipal waste disposal.

Water use in manufacturing is primarily for cooling purposes and therefore contains a very small concentration of contaminants.

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[a] Some plants achieve production rates of 400 to 600 per hour for the gallon container and 450 to 650 per hour for the half gallon container.

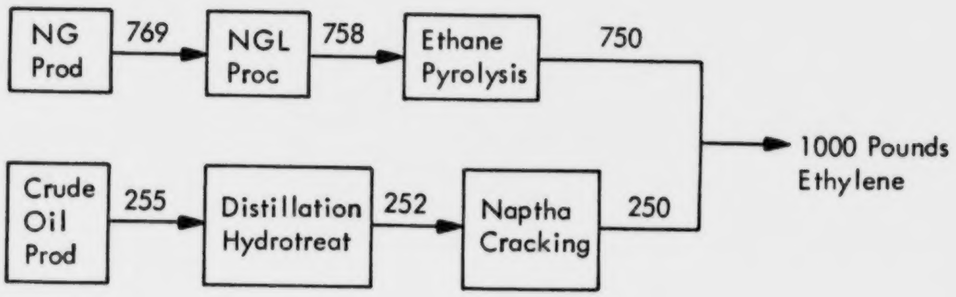
NG
Prod
769
NGL
Proc
758
Ethane
Pyrolysis
750
Crude
Oil
Prod
255
Distillation
Hydrotreat
252
Naptha
Cracking
250
1000 Pounds
Ethylene

Figure 30. Flow diagram for 1,000 pounds of ethylene system (pounds).

TABLE 62

DATA FOR MANUFACTURE OF 1,000 POUNDS OF HIGH DENSITY POLYETHYLENE

Impact category	Value	Source
Raw materials		
Ethylene	1,070 lb	41
Other	50 lb	37
Energy		41,42
Electric	422 kw-hr	
Natural gas	550 cu ft	
Water (wastewater volume)	1,000 gal.	41,47
Solid wastes, process	2.4 lb	41,55
Atmospheric emissions, process		
Hydrocarbons	5.0 lb	40,41,55
Waterborne wastes		
BOD	0.30 lb	47
COD	3.00 lb	47
TSS	0.83 lb	47

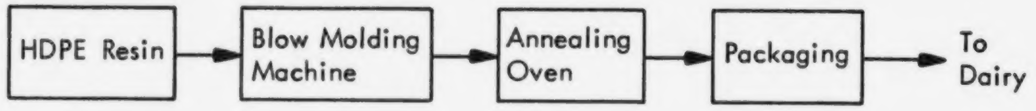
HDPE Resin
Blow Molding Machine
Annealing Oven
Packaging
To Dairy

Figure 31. Diagram for manufacture of refillable plastic milk containers.

The impacts for the manufacture of 1,000 pounds of the refillable plastic milk containers are shown in Table 63. The half pint container is not presenly a commercially produced container; therefore the values for this size are estimates only.

TABLE 63

DATA FOR MANUFACTURE OF 1,000 POUNDS OF
REFILLABLE HDPE MILK CONTAINERS

Impact category	One gallon	Half gallon	Half pint	(Source)
Raw materials				
HDPE resin, lb	1,005	1,005	1,005	37,72
Energy				
Electric, kw-hr	635	774	600	72
Natural gas, cu ft	1,982	2,472	2,472	37,72
Water volume, gal.	2,727	3,312	3,000	72
Process solid waste, lb	5.0	5.0	5.0	37,72

3. Container washing and filling

a. Washing: Bottle washers are available from several vendors and can be manufactured to various specifications. The capacity (bottles per minute) of the washers can vary from around 20 to more than 150.

In the operation of the washer, the soak tank is first filled, usually requiring 820 to 1,400 gallons of water. The soak tank is charged with caustic soda to give a 5 percent solution, and the percentage is maintained by adding approximately 1 pound of caustic per 1,000 bottles washed. Generally, it is necessary for the soak tank solution to be changed only once each 6 months. The soak solution is maintained at 165°F, and due to the low specific heat of the plastic bottles, little heat is lost in heating the bottles.

After a 3- to 6-minute soak time, the bottles are inverted and pressure rinsed in a prewash section to flush out caustic and loosend residue. The water in the prewash tank is maintained around 150°F, with make-up water coming from the wash tank overflow.

The bottles then pass to a wash compartment where spray jets contact each surface inside the bottle. The water is maintained at about 120°F, with make-up water coming from the rinse tank overflow. The bottles then go through an 80°F fresh water rinse and a sanitizing rinse. The sanitizing solution contains chlorine or iodine and is maintained around 125 ppm.

The consumption of fresh water is between 0.3 and 0.43 gallons per bottle, depending on the speed that the machine is running.

Steam is used in the soak, prewash, wash, and rinse tanks to maintain the proper water temperature. Most of the heat required in the soak tank is for warming the bottles. The bottles are passed through the tanks in an every-decreasing temperature range, and the water in these tanks is recirculated to maintain the temperatures. The make-up water system, already described, provides preheated water to the various tanks, effecting considerable energy conservation.

Approximately 125 Btu are required to wash one bottle. Since the boilers are generally heated with natural gas, the total electrical load reduces to approximately 5 watts per bottle washed.

The standard procedure for washing plastic bottles uses a stronger caustic solution and higher temperatures than are used with glass bottles (because the glass may etch or break). However, more heat is removed during washing glass bottles due to the higher specific heat. Therefore, the washing costs for plastic and glass are very similar.

Table 64 contains the basic impact values for washing 1,000 gallons (of capacity) of plastic containers. In the case of the half pint container, estimates were made.

b. Filling: Impact data for filling the plastic bottles are shown in Table 65. The filling rate was assumed to be 75 containers per minute for the gallon size and 120 per minute for the half gallon and half pint sizes.

4. Secondary packaging: The refillable plastic bottles are manufactured by custom blow-molders and shipped to the dairy or a centralized distribution center.

The amount of corrugated packaging used for the gallon and half gallon sizes are shown in Table 66, along with an estimate for the half pint size, which is currently not in production.

TABLE 64

DATA FOR WASHING 1,000 GALLONS OF REFILLABLE PLASTIC CONTAINERS

Impact category	One Gallon	Half gallon	Half pint	Source
Raw materials				
Caustic, lb	2.0	2.0	2.0	37,74
Sanitizer, gal.	0.13	0.13	0.13	37
Energy				
Electric, kw-hr	5.0	10.0	40.0	37,74
Gas, cu ft	121.0	122.0	968.0	37,74
Water volume, gal.	300.0	600.0	2,400.0	37,74
Solid waste, lb	3.0	3.0	3.0	37
Waterborne wastes, lb				
BOD	0.07	0.07	0.07	16,37
Suspended solids	0.105	0.105	0.105	15,37
Alkalinity	2.0	2.0	2.0	37

TABLE 65

DATA FOR FILLING 1,000 GALLONS OF REFILLABLE PLASTIC CONTAINERS

Impact category	One Gallon	Half gallon	Half pint	Source
Energy				
Electric, kw-hr	1.5	1.92	1.92	37,75
Solid wastes, lb	0.4	0.4	0.4	37
Waterborne wastes, lb				
BOD	0.16	0.16	0.16	15,37
Suspended solids	0.24	0.24	0.24	15,37

TABLE 66

PACKAGING REQUIREMENTS FOR 1,000 POUNDS OF REFILLABLE PLASTIC CONTAINERS

Container size	Pounds of corrugated
Gallon	198
Half gallon	198
Half pint	198

Source: Midwest Research Institute.

5. Transportation profile: The transportation for the refillable plastic container system is presented in Table 67. These values represent the ton-miles of transportation for 1,000 pounds of containers. For the 5-trip container the transportation impacts would be one-fifth the values in Table 67, etc. The largest transportation impacts would be assigned to the resin transport, and the transport of the containers would show the second largest impact values.

TABLE 67

TRANSPORTATION PROFILE FOR 1,000 POUNDS OF REFILLABLE PLASTIC CONTAINERS (ton-miles)

	Transportation mode			
System component	Rail	Truck	Barge	Pipeline
Crude oil	-	0.3	1	3
Natural gas	-	-	-	4
Ethane	4	1.0	1	6
Ethylene	5	1.0	-	-
Polyethylene resin	38	7.0	-	-
Plastic containers	5	15.0	-	-
Closures	2	3.0	-	-
Packaging	7	9.0	-	-

Source: Midwest Research Institute.

Table 68 summarizes the fuel requirements for delivery of 1,000 gallons of milk in each refillable plastic system. The assumption used for calculating the fuel requirements are: (a) store delivery = 60-mile round trip, with an average load of 828 cases; (b) home delivery = 60-mile round trip plus 17.5 miles home delivery, average load is 225 cases; and (c) fuel consumption is 5 miles per gallon.

TABLE 68

DELIVERY OF 1,000 GALLONS OF MILK IN
EACH REFILLABLE PLASTIC CONTAINER
(gallons of fuel)

Delivery market	One Gallon	Half gallon	Half pint
Store delivery (90%)			
Gasoline	1.62	1.62	1.80
Diesel	1.62	1.62	1.80
Home delivery (10%)			
Gasoline	1.7	1.7	

Source: Midwest Research Institute.

The fuel required to deliver a unit volume of milk is primarily dependent upon the number of containers which the truck can carry during one trip. A typical 40-foot trailer truck (store delivery) can carry 828 cases (3,312 gallons) of one gallon plastic containers, but approximately 647 cases (2,588 gallons) of one gallon glass containers. The limiting factor is the maximum weight which the truck can carry. The home delivery truck can carry approximately 225 cases (900 gallons) of plastic containers. Table 69 shows the relationship of the components of the milk delivery system for the one gallon refillable plastic bottle.

TABLE 69

WEIGHT ANALYSIS FOR DELIVERING 1,000 GALLONS OF MILK IN THE REFILLABLE GALLON PLASTIC CONTAINER

Component	Weight in pounds	Weight as percent of total
Containers	352.73	3.5
Closures	5.07	0.05
Cases (250, 4 lb each)	1,000.00	10.0
Milk	8,600.00	86.4
Total	9,957.80	100.0

Source: Midwest Research Institute.

The containers and closures represent only 3.55 percent of the total we[illegible] in the truck. The 1,000 gallons of milk represents 86.4 percent of [illegible]ayload. In contrast, the delivery of 1,000 gallons of milk in the g[illegible] one gallon container would show 3,205 pounds (25 percent) of glass plus closures, 1,000 pounds (11 percent) of cases and 8,600 pounds (65 percent) of milk.

In delivering 1,000 gallons of milk, the half gallon refillable plastic container would represent 5.5 percent of the total weight, while the half pint would represent 11.3 percent of the total weight. The total weight (container, closure, case, and milk) for 1,000 gallons of milk in each refillable plastic system is shown in Table 70 below.

TABLE 70

DELIVERY WEIGHTS FOR 1,000 GALLONS OF MILK IN REFILLABLE PLASTIC

Container size	Total weight, lb	Ratio to one gallon container
One gallon	9,958	1.00
Half gallon	10,166	1.02
Half pint	10,822	1.09

Source: Midwest Research Institute.

The ratios of the half gallon and half pint weights to the weight for the one gallon container show that the fuel requirements for delivering 1,000 gallons in each container size would be very similar.

6. Postconsumer solid waste and recycling: The refillable plastic containers are assumed to compress to 60 percent of air original volume (Ref. 89) during landfill operations. The total volume occupied by the containers would be the sum of: (a) the volume of the plastic materials; (b) 60 percent of the original volume of the containers; and (c) the volume of the closure materials. The amount reaching the landfill would be 91 percent of the original quantity of bottles, with 9 percent being incinerated.

At present, the general method for discarding the refillable plastic containers is to place them in the municipal waste stream, rather than return the bottles to a blow-molder for recycling. However, the used containers represent a valuable source of plastic that could be reclaimed for material or energy uses. As the refillable plastic container becomes more widely used, the number returned for recycling should increase. In this study it was assumed that all of the refillable plastic containers enter the solid waste stream.

Plastic containers also represent a valuable source of energy. One pound of polyethylene has an energy value of about 20,050 Btu. Therefore, 1,000 pounds of the plastic containers would represent an energy resource of over 20 million Btu. In this study, the energy content of the discarded containers has not been credited to the plastic systems. At present, the amount of plastic recovered for use as a fuel is quite small. However, as the number of resource recovery units based on mixed solid waste increase, the fuel value of the plastic material in the solid waste stream will be recovered.

D. Nonrefillable Plastic Bottle

1. Raw material extracting and processing: The types of raw materials required for the nonrefillable plastic container are identical to those described for the refillable plastic bottle. The data for crude oil production, natural gas production, natural gas processing, crude distillation/hydrotreat, ethylene manufacture, and HDPE resin manufacture are presented in Section C-1.

2. Nonrefillable plastic milk container manufacture: High density polyethylene nonrefillable milk containers are manufactured using blow-molding systems (Figure 32). The resin is fed to a molding machine which will produce approximately 1,400 one gallon; 2,880 half gallon; and 7,200 half pint milk bottles per hour. The bottles are trimmed, decorated, and conveyed to packaging lines if manufactured by a custom blow-molding operation, or to the milk filling machines if manufactured in the dairy. Custom molders provide about 50 percent of the plastic containers used in the dairy industry.

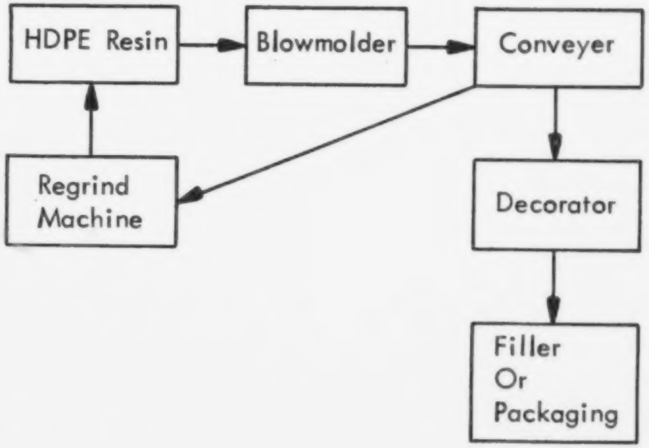
HDPE Resin
Blowmolder
Conveyer
Regrind Machine
Decorator
Filler Or Packaging

Figure 32. Diagram for nonrefillable plastic container manufacture.

The plastic trimmings and container rejects are processed in a regrinder and used as raw material for the blow-molder. The amount of plastic scrap going to municipal waste disposal is estimated to be 1.5 percent of production.

The energy consumption for manufacturing the nonrefillable plastic containers includes the requirements for blow-molders, decorators, material handling, chillers, regrind equipment, and air compressors.

The impact data for manufacturing 1,000 pounds of nonrefillable HDPE milk containers are given in Table 71.

3. Container filling: The impacts for filling and capping the plastic containers are shown in Table 72. The fill rate is assumed to be 50 containers per minute for the gallon size and 120 per minute for the half gallon and half pint sizes.

The losses were assumed to be 0.5 percent of output. In filling 1,000 gallons of milk 5 gallons are assumed to be lost, or 43 pounds of milk. Each pound of milk contains approximately 0.104 pounds of BOD. Therefore, the milk wastes would contain 4.4 pounds of BOD. BOD is generally reduced by 96.2 percent, and the amount of BOD released would be 0.16 pound for each 1,000 gallons of containers filled (Ref. 15). The suspended solids are reported to be 1.5 times the BOD quantities, or 0.24 pound per 1,000 gallons of milk (Ref. 15).

4. Secondary packaging: In the dairy industry, approximately 50 percent of the containers are manufactured by custom blow-molders, and require packaging and transportation to the dairy. Typically, a custom molder would package the empty container in plastic bags having cardboard dividers. A plastic bag 23-1/2 by 20 by 63 inches plus two cardboard dividers, 18-1/2 by 20-1/2 and 23 by 24 inches, will carry 48 one gallon containers.

The quantities of plastic and corrugated packaging associated with shipping 500 pounds of bottles are shown in Table 73. Values for the half gallon and half pint are estimates based on the requirements for the one gallon size. These values represent the packaging requirements for 1,000 pounds of nonrefillable plastic containers since about one-half of the containers are made in the dairy and require no packaging.

5. Transportation profile: The ton-miles of transportation assigned to the nonrefillable plastic bottle systems are presented in Table 74. The resin subsystem transportation (including transportation for crude oil, natural gas, ethane, ethylene, and polyethylene resin) shows the highest ton-mile values in each container profile. Transport of the containers shows the second highest ton-miles.

TABLE 71

DATA FOR MANUFACTURING 1,000 POUNDS OF NONREFILLABLE HDPE MILK CONTAINERS

Impact category	One gallon	Half gallon	Half pint	Source
Raw materials				
HDPE resin, lb	1,020	1,020	1,020	36,37
Energy				
Electric, kw-hr	391	394	396	36,37
Water volume, gal.	1,600	1,400	2,100	37
Industrial solid waste, lb	20	20	20	37,73

TABLE 72

DATA FOR FILLING AND CAPPING 1,000 GALLONS OF PLASTIC CONTAINERS

Impact category	One Gallon	Half gallon	Half pint	Source
Energy				
Electric, kw-hr	2.34	1.92	15.4	37,75
Solid waste, lb	0.4	0.4	0.4	37
Waterborne wastes, lb				
BOD	0.16	0.16	0.16	15,37
Suspended solids	0.24	0.24	0.24	15,37

TABLE 73

PACKAGING FOR ONE-WAY PLASTIC CONTAINERS

Container size	Pounds per 1,000 pounds of bottles[a] Plastic	Pounds per 1,000 pounds of bottles[a] Cardboard
Gallon	38.5	76.9
Half gallon	33.4	66.6
Half pint	33.4	66.6

Source: Midwest Research Institute.

[a] Includes packaging for only 500 pounds of bottles since 50 percent are manufactured in the dairy.

TABLE I-74

TRANSPORTATION PROFILE FOR 1,000 GALLONS OF THE NONREFILLABLE PLASTIC CONTAINER SYSTEMS
(ton-miles)

Subsystem	One gallon[a] R	One gallon[a] T	One gallon[a] B	One gallon[a] PL	Half gallon R	Half gallon T	Half gallon B	Half gallon PL	Half pint R	Half pint T	Half pint B	Half pint PL
HDPE resin system transport	65	13	3	19	74	15	3	24	197	90	8	56
Container transport		15				17				41		
Closure system transport	2	2			4	4		1	10	9		3
Packaging system transport	3	2			4	2			9	5		2
Totals	70	32	3	19	82	38	3	25	216	145	8	61

Source: Midwest Research Institute.

[a] R = Rail; T = Truck; B = Barge; PL = Pipeline.

The fuel requirements for delivering 1,000 gallons of milk in each nonrefillable plastic system are assumed to be the same as the data presented in Table 68.

The data in Table 75 summarize the weights of containers, closures, etc., for delivering 1,000 gallons of milk. The total weights in each size container are very close in magnitude. They are also very close to those for the refillable plastic systems (Table 78). Therefore, the fuel consumption for delivering 1,000 gallons of milk in the refillable plastic container (Table 68), has also been assigned to the nonrefillable plastic systems.

TABLE 75

WEIGHT ANALYSIS FOR DELIVERY OF 1,000 GALLONS OF MILK IN THE NONREFILLABLE PLASTIC SYSTEMS

Component	One gallon		Half gallon		Half pint	
	lb	%	lb	%	lb	%
Containers	154.3	1.6	176.4	1.8	423.3	4.2
Closures	5.0	0.05	10.1	0.1	22.9	0.2
Cases	1,000.0	10.2	1,000.0	10.2	1,000.0	10.2
Milk	8,600.0	88.1	8,600.0	87.9	8,600.0	85.6
Total	9,759.3	100.0	9,786.5	100.0	10,046.2	100.0

Source: Midwest Research Institute.

6. Postconsumer solid waste and recycling: The postconsumer solid waste profile for the nonrefillable plastic container systems is calculated with the same assumptions that were used for the refillable plastic containers. The total volume of solid waste in the landfill is the sum of the material volume and void volume, assuming that 60 percent of the original container volume remains as void space in a landfill. Also, 91 percent of the solid waste is landfilled and 9 percent is incinerated.

E. Nonrefillable Paperboard Carton

1. Raw materials extracting and processing

a. Pulpwood harvesting: Impacts incurred during logging activities were determined from specific company operating data (Ref. 22). The primary impacts incurred are related to fuels required for the cutting of timber and hauling it to a landing. The timber is then transported directly to a papermill, or in many cases, to a concentration point which serves as a point of origin for shipping logs gathered from several "landings" to the mill.

Impacts were considered here only from roundwood consumption. The wood delivered to mills surveyed by the American Paper Institute for this study is 52 percent roundwood, the remainder being wood chips or wood residues obtained from other types of wood processing (Ref. 23). However, in past years, chips and other wastes were burned, rather than used, so they are treated as a waste by-product from another industry.* Hence, less environmental impact is attributed to wood harvesting than if the wood were all supplied as roundwood. The impacts of harvesting wood which ends up as chips are also allocated to the primary product for which it was harvested. Thus, the impacts of wood ending up as sawdust are allocated to lumber products and are not included here. In addition, in the case of the specific paperboard mills studied, the wood residues are generated on-site, or quite close by so that the transport of the residues is negligible.

Table 76 summarizes the data pertaining to pulpwood harvesting. Gasoline represents the fuel used for cutting and hauling the logs. Atmospheric emissions were derived by estimating the effluents from the burning of wood wastes left in the forest.

TABLE 76

DATA FOR HARVESTING 1,000 POUNDS PULPWOOD

Category	Value
Energy	
Gasoline	0.89 gal.
Atmospheric pollutants	0.14 lb

Source: Reference 22.

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* In other words, the impacts of wood residues are assigned to the primary wood product itself.

The factors used were as follows:

(1) Ten percent of the harvested roundwood is left in the woods as a residue (Ref. 22).

(2) Seven percent of the amount left is presently burned (Ref. 22).

(3) Two percent of the amount burned is emitted into the atmosphere as a particulate emission (Refs. 22 and 24). Thus, for 1,000 pounds of wood harvested, there are 100 pounds of waste, 7 pounds of which are burned. Of these 7 pounds, 2 percent, or 0.14 pound, is emitted to the atmosphere as particulates.

One item of possible significance is omitted from Table 76. An unknown amount of water pollution in the form of suspended solids results from run-off from road building in the harvested forests. However, at present, it is not possible to estimate accurately to what extent these solids actually reach streams. Although perhaps 7 pounds of suspended solids are generated, their final deposition is probably at other locations within the forest, and not in streams (Ref. 21). Therefore, this category was not included at this time because the amount of stream pollution from this source is quite likely very small, and could not be determined from published or unpublished sources.

Some of the remaining raw materials required for paperboard manufacture are salt, limestone, lime, sulfur and sulfuric acid. These materials are all discussed in other sections of this appendix (principally the glass section). Chlorine-caustic and other papermaking chemicals are summarized in the sections which follow.

b. Chlorine manufacture: Approximately 97 percent of the chlorine produced in the United States is manufactured by electrolytic caust-chlorine processes (Figure 33). The remainder comes from a nitrosyl chloride process, electrolysis of hydrochloric acid, and as a by-product from the electrolytic production of caustic potash, magnesium, and metallic sodium.

The electrolysis of sodium chloride is performed by two processes: (1) mercury cathode cells; and (2) diaphragm cell. The mercury cell produces about 24.2 percent of the electrolytic chlorine while the diaphragm cell accounts for about 75.8 percent.

The mercury cathode cell process can be described as follows:

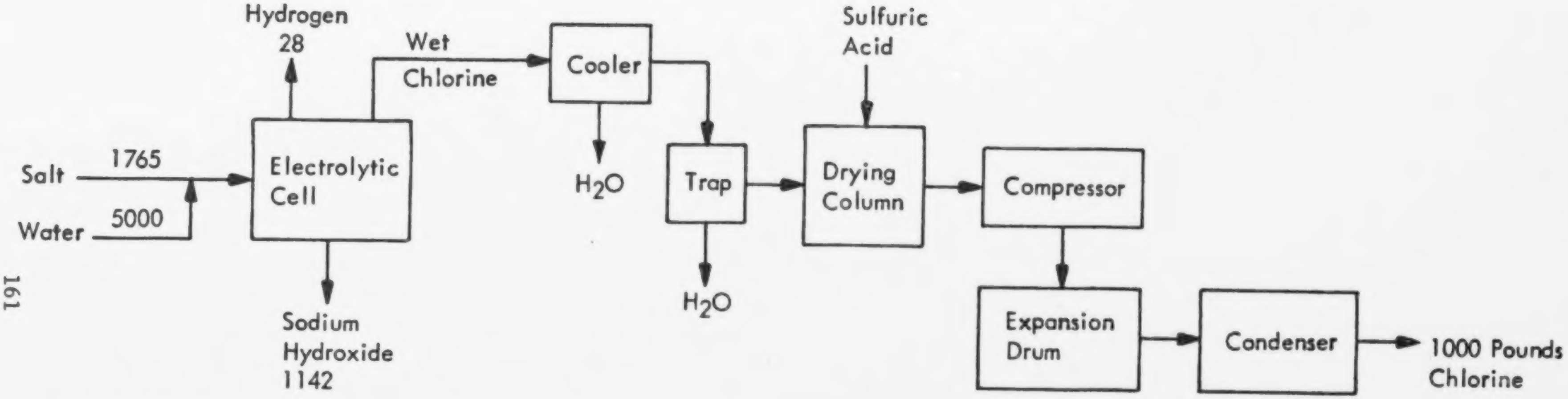

Salt
1765
Water
5000
Hydrogen
28
Electrolytic Cell
Sodium Hydroxide
1142
Wet Chlorine
Cooler
H_2O
Trap
H_2O
Sulfuric Acid
Drying Column
Compressor
Expansion Drum
Condenser
1000 Pounds Chlorine

Figure 33. Manufacture of 1,000 pounds of chlorine and by-products, diaphragm cell.

$$NaCl + xHg^{\circ} = 1/2\ Cl_2 + Na\ (Hg)x \text{ and}$$

$$Na(Hg)x + H_2O = NaOH + 1/2\ H_2 + xHg^{\circ}$$

The salt is electrolyzed, producing chlorine gas at the graphite (or metal) anodes; metallic sodium, released by the passage of current, reacts with the mercury cathode to produce an amalgam. The amalgam is sent to another compartment of the cell where it reacts with water to produce hydrogen and very pure sodium hydroxide. The outstanding feature of the mercury cell is the high grade and concentration of the caustic liquor, which may be used in other industries without further purification. The disadvantages of the mercury cell are its higher energy requirements and loss of mercury. Some of the methods by which mercury can escape the plant are (Ref. 68):

(1) Carryover in the hydrogen gas stream;

(2) Cell room ventilation air;

(3) Washing water from cell rooms;

(4) Purging of the brine loop;

(5) Disposal of brine sludges; and

(6) End box fumes.

Close attention to product and effluent stream is necessary to keep the mercury loss at a minimum. The average mercury consumption from this type of plant in 1972 was 0.183 pound per 1,000 pounds of chlorine produced (Ref. 61). This value is based on the 1972 production of chlorine from mercury cells, which was 2,389,356 short tons, and mercury purchases of 11,519 flasks (875,444 pounds).

The diaphragm cell uses graphite anodes and steel cathodes. The brine solution is passed to the anode compartment where chlorine gas is formed and taken off through a pipe at the top of the cell. The other ions in solution flow through an asbestos diaphragm and react at the cathode to form sodium hydroxide and hydrogen. The diaphragm prevents back diffusion of the cathode reaction products. The caustic-brine solution containing hydrogen is removed from the cathode compartment and processed to recover hydrogen and caustic. The chlorine from the anode compartment is cooled and then dried in a sulfuric acid scrubber. The gas is compressed and cooled to form liquid chlorine. Shipment of chlorine is generally by rail and barge.

Table 77 shows the data pertaining to the manufacture of chlorine.* The manufacturing data are a combination derived by adding 24.2 percent of the mercury cathode cell impacts to 75.8 percent of the diaphragm cell impacts.

The largest impact is the amount of electrical energy required to operate the cells. About 21 million Btu are required for the 2,170 pounds of products. The amount allocated to chlorine is about 9.5 million Btu.

About 5,000 gallons of water per 1,000 pounds of chlorine are used in cooling. Assuming that the water is recycled twice, make-up volume would be 1,667 gallons per 1,000 pounds. Process wastewater amounts to about 75 gallons per 1,000 pounds of chlorine. Total water requirements are estimated to be 1,742 gallons per 1,000 pounds of chlorine (801 gallons with by-product credit).

The solids value was estimated by calculating the amount of sludge produced during the manufacturing process. The brine sludges contain about 50 parts per million mercury.

The quantity of salt allocated to production of 1,000 pounds of chlorine is 1,071 pounds. The sodium content of the salt raw material represents part of the by-product sodium hydroxide, and should not be counted as a raw material for chlorine.

c. Sodium hydroxide manufacture: The electrolytic method for manufacture of sodium hydroxide (caustic soda) accounts for more than 90 percent of the total U.S. production. The caustic is actually a by-product of the chlorine manufacturing process described in the previous section.

Table 78 contains the basic impacts for the production of 1,000 pounds of caustic.

d. Sodium hypochlorite manufacture: Sodium hypochlorite (NaOCl) is commonly manufactured by passing chlorine gas through a dilute caustic soda solution (Figure 34). The equation for the reaction is:

$$Cl_2 + 2NaOH = NaOCl + NaCl + H_2O$$

---

* The mercury discharge profile for this report is based on the publication, "Canadian Experience with the Reduction of Mercury at Chlor-Alkali Plants," by F. J. Flewelling, and information received from The Chlorine Institute, Inc., in New York City.

TABLE 77

DATA FOR MANUFACTURE OF 1,000 POUNDS OF CHLORINE

Impact category	Value	Source
Raw materials		37,61
Sodium chloride	1,071.00 lb	
Graphite	1.63 lb	
Asbestos	0.18 lb	
Sulfuric acid	4.60 lb	
Mercury	0.020 lb	
Hydrochloric acid	1.20 lb	
Sodium carbonate	8.37 lb	
Energy		37,70
Electric	772.0 kw-hr	
Water volume	801.0 gal.	69
Process solid wastes (mercury - 0.019)	80.0 lb	37,69
Process atmospheric emissions		37,69,71
Mercury vapor	0.0007 lb	
Chlorine	4.13 lb	
Waterborne wastes		37,69,71
Mercury	0.0001 lb	
Suspended solids	0.20 lb	
Lead	0.006 lb	
Transportation		37
Rail	400 ton-miles	
Barge	400 ton-miles	

TABLE 78

DATA FOR MANUFACTURE OF 1,000 POUNDS OF SODIUM HYDROXIDE

Impact category	Value	Source
Raw materials		37,61
Sodium chloride	608.0 lb	
Graphite	1.63 lb	
Asbestos	0.18 lb	
Sulfuric acid	4.60 lb	
Mercury	0.045 lb	
Hydrochloric acid	1.20 lb	
Sodium carbonate	8.37 lb	
Energy		
Electricity	772.0 kw-hr	37,70
Water volume	801.0 gal.	69
Process solid wastes	80.0 lb	37,69
Process atmospheric emissions		37,69,71
Mercury vapor	0.0007 lb	
Chlorine	4.13 lb	
Waterborne wastes		37,69,71
Mercury	0.0001 lb	
Suspended solids	0.20 lb	
Lead	0.006 lb	
Transportation		37
Rail	109 ton-miles	
Barge	57 ton-miles	
Truck	12 ton-miles	

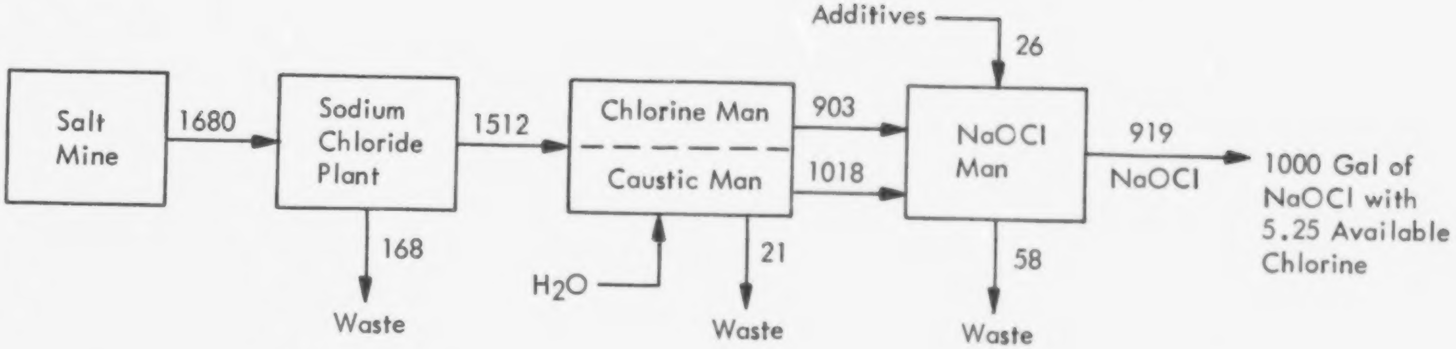

Salt
Mine
1680
Sodium
Chloride
Plant
168
Waste
1512
Chlorine Man
Caustic Man
H_2O
21
Waste
903
1018
Additives
26
NaOCl
Man
58
Waste
919
NaOCl
1000 Gal of
NaOCl with
5.25 Available
Chlorine

Figure 34. Flow diagram for manufacture of sodium hypochlorite.

By assuming a 3 percent loss of raw materials during the manufacturing step, the quantity of raw materials required to produce 1,000 gallons of 5.52 percent NaOCl are:

Chlorine	439 lb
Sodium hydroxide	495 lb

By product credit was not given for the sodium chloride produced.

Table 79 shows the manufacturing data for producing 1,000 gallons of 5.25 percent NaOCl.

TABLE 79

DATA FOR PRODUCTION OF 1,000 GALLONS OF SODIUM HYPOCHLORITE
(438 pounds of sodium hypochlorite per 1,000 gallons)

Impact category	Value	Source
Raw materials		37,49
Material process additions	26 lb	
(Chlorine - 439 lb)		
(Caustic - 495 lb)		
Energy		37
Electric	123.0 kw-hr	
Water volume	5,040.0 gal.	37
Solid wastes process	37 lb	37
Atmospheric emissions		
Chlorine	10.5 lb	37
Waterborne wastes		
Dissolved solids	10.5 lb	37
Transportation		
Rail	140.0 ton-miles	
Truck	28.0 ton-miles	
Barge	36.0 ton-miles	

The energy value is an estimate of the requirements to operate the stirrers, conveyors, etc., and to produce ice, which is normally used to cool the solution.

2. Bleached kraft pulp and paperboard manufacture: Kraft pulp is the most widely used type of wood pulp in the United States today, accounting for 70 percent of the total wood pulp produced. It is used in either an unbleached or bleached form. Paperboard milk cartons are made of bleached kraft paperboard.

The kraft pulping process is based on chemical digestion of wood which has been previously debarked and chipped. The digester is a closed container which holds the wood chips and digestion liquors.

The liquor is mainly an aqueous solution of chemicals including sodium sulfide and sodium hydroxide. In order for digestion to take place, heat and pressure are applied to the mixture of wood and liquor. The digestion process delignifies the wood and removes other chemical components from the wood, leaving only the wood fiber. After the wood pulp is "blown" from the digester by the steam used in the process, it is washed free of the chemicals, screened and refined for entry into the paper-forming section of the mill.

One of the features of the kraft process is that the used digestion liquor, called black liquor, is burned. The liquor contains a high percentage of flammable wood components and so it burns readily. The digestion chemicals are removed in the process and heat is released from the organic components. Black liquor combustion, plus the use of the bark removed from the incoming logs as a fuel, provides sufficient energy to operate a pulp mill. Thus, there is no fossil fuel requirement for the pulp-making process, although additional energy from fossil fuel sources is used in the paper-forming steps which immediately follow pulp making.

The quantity of constituent chemicals removed from the wood which is actually burned in the recovery furnace has been subtracted from the virgin raw materials requirements because it has been treated as a usable coproduct fuel in the analysis.

Once the pulp is produced and bleached, it is sent in a water slurry to the paperboard manufacture section of the mill. There, the slurry is placed on a wire or plastic mesh from which the water drains, leaving a paperboard mat. The paperboard is pressed and dried in a long series of steam-heated driers before being wound on rolls. Then the paperboard is extrusion-coated with polyethylene, usually at the mill site, and the rolls of paperboard are shipped to a converting plant for fabrication into milk carton blanks.

The materials used in paper manufacturing are shown in Figure 35. On a weight basis, wood fiber is 78 percent of the total, and the wood fiber comes from two distinct sources. Trees, harvested specifically for wood pulp manufacture, accounts for 53 percent of the wood fiber. The remainder comes from wood residues (sawdust and chips) generated by lumber manufacture, or other wood processing. Thus, if the 999 pounds of wood fiber required for 1,000 pounds paperboard manufacture, only 530 pounds of this actually comes directly from trees; the remainder comes from wood residues created in other types of wood processing operations.

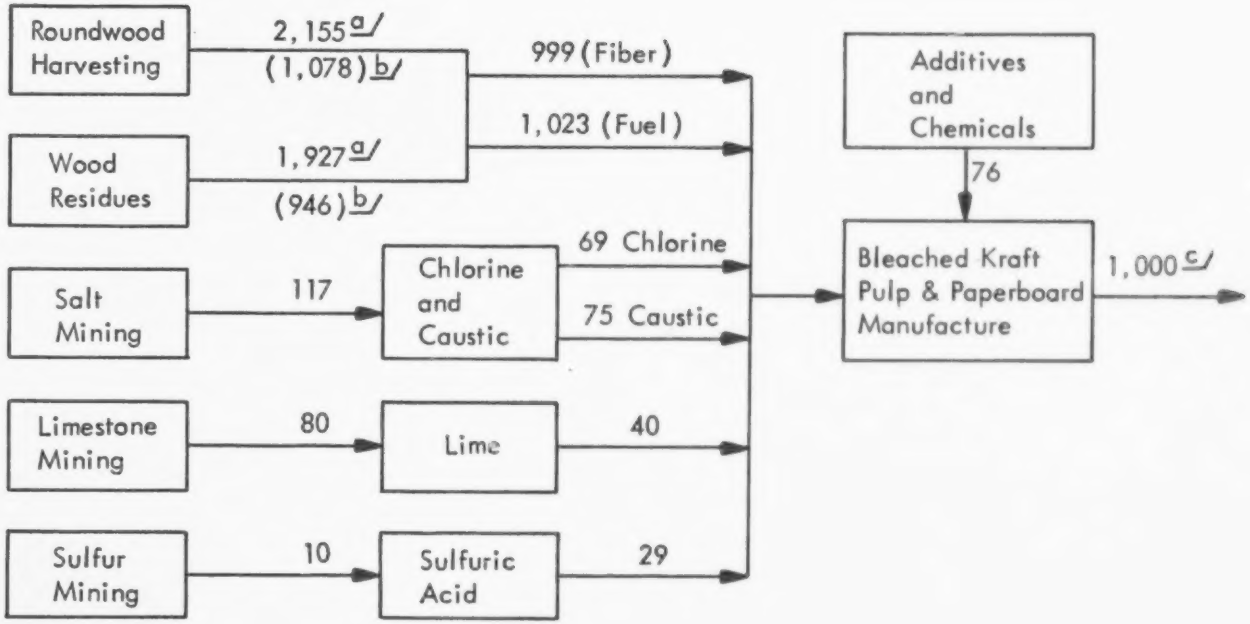
In order to obtain the most representative data possible for this study, a survey was made of the specific bleached kraft paperboard mills in this country which manufacture milk packaging paperboard (Ref. 25). The results of this survey are summarized in Table 80, where the data needed to derive the impact profiles are listed. Although the completeness of data coverage for the total industry varied from item to item in Table 80, the data sources represent approximately 70 percent of the milk carton paperboard tons produced. The data are the most current available (July 1975) and generally represent 1974 values. (Only 1973 energy data were available in a complete form, but 1974 values were derived from a separate paper industry 1974 energy survey.)

One important inclusion in this profile is the energy required for plastic extrusion and coating of the paperboard. Although coating is included as part of the converting operation, 71.5 percent of the coated paperboard milk carton stock is coated at or near the papermill site. The energy values in Table 80 reflect the inclusion of the energy for 71.5 percent of the extrusion and coating at the papermill because these data could not be separated from the energy data for other mill operations.

The most significant feature of the energy usage is the utilization of wood fiber as an energy source. For the 9.53 million Btu shown, 17 percent is derived from bark and other solid wood wastes, while the remainder is derived from spent draft digestion liquor. The use of this wood waste greatly reduces dependence on fossil fuels for pulp and papermaking.

The remainder of the data in Table 80 represent effluent values which are now being achieved by the mills studied. The values which will be experienced in 1977 will be at least this low, but they are presently at or below 1977 requirements; thus these values were not reduced further for purposes of calculations.

In order to complete the impact profile calculations, data were collected on the effluents resulting from burning fuels at the mill site for power production. In a companion survey to the one used to derive Table 80 data were collected on purchased fuel atmospheric emissions. These data are in Table 81. The effluents from the power sources are


Roundwood Harvesting
2,155 a/
(1,078) b/
Wood Residues
1,927 a/
(946) b/
999 (Fiber)
1,023 (Fuel)
Salt Mining
117
Chlorine and Caustic
69 Chlorine
75 Caustic
Limestone Mining
80
Lime
40
Sulfur Mining
10
Sulfuric Acid
29
Additives and Chemicals
76
Bleached Kraft Pulp & Paperboard Manufacture
1,000 c/

Source: Based on data in Reference 25.

a/ As received, includes moisture.

b/ Dry fiber base. It was assumed that 50 percent of the wood as received was moisture.

c/ Does not include weight of plastic coating.

Figure 35. Materials flow for manufacture of 1,000 pounds bleached kraft paperboard.

TABLE 80

DATA FOR MANUFACTURE OF 1,000 POUNDS BLEACHED KRAFT PULP AND PAPERBOARD

Impact category	Value
Materials, lb	
Roundwood (trees)	2,155 (1,078 lb dry weight)
Wood residues (sawdust, etc.)	1,927 (944 lb dry weight)
Total wood	4,082 (2,022 lb dry weight)[a]
Chlorine	69
Caustic	75
Lime	40
Sulfuric acid	29
Other chemicals and additives	76
Energy	
Electricity, kw-hr	209
Residual, gal.	34.1
LPG, gal.	4.73
Natural gas, cu ft	2,258
Coal, lb	245
Wood, million Btu	9.53
Water, gal.	10,700
Industrial solid wastes, lb	119
Atmospheric pollutants, lb[b]	
Particulates	2.21
Sulfur oxides	0.23
Nitrogen oxides	0.46
TRS[c]	0.4
Waterborne pollutants, lb	
Suspended solids	7.8
BOD	4.4

Source: Reference 25.

[a] Includes 999 pounds for fiber and 1,023 pounds for fuel.

[b] Excludes power sources.

[c] Total reduced sulfur.

only the on-site effluents, so these data must be combined with the secondary emission factors to include mining and processing of fuels, etc.

TABLE 81

EMISSIONS TO THE ATMOSPHERE FROM PAPERMILL SITES FOR MANUFACTURE OF 1,000 POUNDS BLEACHED KRAFT PAPERBOARD[a]
(in pounds)

Air emission category	Kraft process	Power sources
Particulates - lb	2.21	2.37
Sulfur oxides - lb	0.23	8.68
Nitrogen oxides - lb	0.46	4.19

Source: Reference 25.

[a] These are the results of a special survey of milk packaging mills (Ref. 25).

This was done by combining the power source emissions (Table 81), with secondary impacts calculated by using the amounts of fuel required (Table 80) and the secondary factros in Table 38 of Section A. The results are found in Table 82.

3. Paperboard container manufacture: Rolls of paperboard coming from the end of the papermill driers are converted into various types of products. In the case of milk containers, the paperboard is coated with an extruded polyethylene film, and then cut and formed into a milk carton blank. These flattened blanks are then shipped to dairies, where they are assembled into the final container.

For 71.5 percent of the paperboard produced, the coating operation takes place at the mill, after which the coated paperboard is shipped to another conversion site for final manufacture of the blank. The remaining 28.5 percent is shipped uncoated from the mill to the converting plant. The energy values in this section include only 28.5 percent of the energy of extrusion, while the other 71.5 percent was reported with the mill data, where in fact, the energy is actually expended.

TABLE 82

IMPACT FACTORS FOR FUEL PURCHASED AND CONSUMED ON-SITE FOR MANUFACTURE OF 1,000 POUNDS BLEACHED KRAFT PAPERBOARD[a]

Impact category	Value
Energy - million Btu	
Residual	5.79
Natural gas and LPG	2.93
Coal	3.26
Solids - lb	47.8
Air pollutants - lb	
Particulates	2.99
Nitrogen oxides	6.45
Hydrocarbons	4.23
Sulfur oxides	10.1
Carbon monoxide	1.27
Water pollutants - lb	
Dissolved solids	3.27
Acid	0.50
Metal ion	0.12
Other	0.39

Source: Franklin Associates, Ltd., for Midwest Research Institute.
[a] Includes secondary fuel factors from Table 38, Section A.

Figure 36 is a diagram showing the material flow into and out of each of the principal processes in paperboard carton manufacture. The diagram contains the values for three carton sizes--one gallon, half gallon, and half pint. As shown, the converting plant receives polyethylene (for coating), paperboard, and other materials (adhesives, inks, and corrugated shipping containers). The paperboard scrap generated in the converting plant is valuable wastepaper, and is recycled to the papermill. The remaining inputs to the converting plants are shipped out as useful products to the dairies (except for a small amount of solvents from inks and adhesives which are collected in the plant and incinerated, and a small amount of contaminated scrap which is discarded). Table 83 contains the detailed data pertaining to the converting operation.

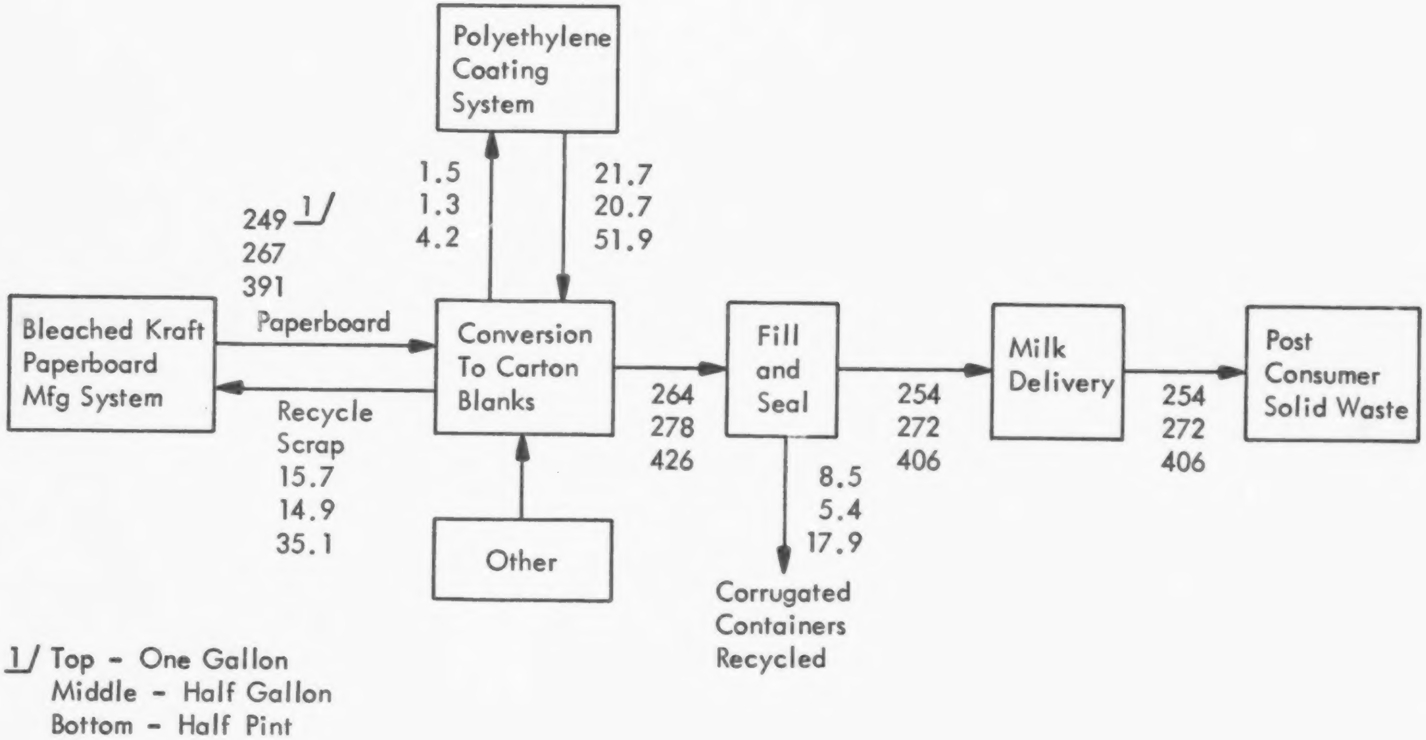

Polyethylene Coating System
1.5
1.3
4.2
21.7
20.7
51.9
249 1/
267
391
Paperboard
Bleached Kraft Paperboard Mfg System
Conversion To Carton Blanks
Recycle Scrap
15.7
14.9
35.1
Other
264
278
426
Fill and Seal
8.5
5.4
17.9
Corrugated Containers Recycled
254
272
406
Milk Delivery
254
272
406
Post Consumer Solid Waste
1/ Top - One Gallon
Middle - Half Gallon
Bottom - Half Pint

Figure 36. Materials flow diagram for 1,000 gallons of milk delivered in paperboard cartons.

TABLE 83

DATA FOR CONVERTING 1,000 POUNDS OF PAPERBOARD TO MILK CARTON BLANKS
(by container size)

Category	One gallon	Half gallon	Half pint
Materials[a]			
Bleached kraft paperboard, lb	976.0	978.0	958.0
Polyethylene, lb	85.0	75.8	127.0
Other, lb	42.0	27.1	53.9
Energy[b]			
Electricity, kw-hr	13.8	13.8	13.8
Natural gas, cu ft	104.0	104.0	104.0
Distillate, gal.	0.004	0.004	0.004
Gasoline, gal.	0.015	0.015	0.015
LPG, gal.	0.059	0.059	0.059
Industrial solid waste, lb	1.0		

Source: Reference 25.

[a] These values include the material input to the conversion plant, including material that is subsequently recycled.

[b] Same for all three sizes.

4. Container filling: Paperboard cartons are received by the dairy in the form of flattened blanks. A wide variety of equipment is used at the dairy to form these blanks into containers and fill them with milk. Either automatic or semiautomatic machinery forms the blank into a rectangular upright container. The bottom is then sealed by using heat to melt the polyethylene coating, and the flaps are pressed into place. In some cases, the side seam is formed at the dairy also, but usually this is done by the converter. The carton is then filled with milk, and the top is sealed in a similar manner.

Table 84 summarizes the impacts associated with paperboard carton filling and sealing. The energy data were obtained from measurements made on operating equipment.

TABLE 84

DATA FOR FILLING AND SEALING 1,000 GALLONS PAPERBOARD CONTAINERS

Category	Gallon	Half gallon	Half pint	Source
Energy				26
Electricity, kw-hr	10.0	11.0	34.0	
Natural gas, cu ft	40.0	55.0	-	
Solid waste, lb	0.43	0.43	0.43	15
Waterborne wastes, lb				
BOD	0.16	0.16	0.16	
Suspended solids	0.24	0.24	0.24	

Source: Franklin Associates, Ltd. for MRI.

The solid waste and water pollutant numbers are based on 1977 federal water pollution standards and are calculated on the basis of a 0.5 percent loss of filled milk.

5. Secondary packaging: The only secondary packaging associated with paperboard cartons is a small amount of corrugated paperboard used to ship carton blanks to the dairies. This amounts to 8.5 pounds of corrugated per 1,000 gallons of milk for one gallon carton sizes; 5.4 pounds per 1,000 gallons of milk for half gallon sizes; and 17.9 pounds per 1,000 gallons of milk for half pint sizes.

6. Transportation profile: The transportation profile for paperboard is shown on Table 85. The values for delivery were calculated in the same manner as for plastic, assuming that a large truck can haul 828 cases of milk in paperboard, as compared to 647 cases in glass; and a home delivery truck can haul 225 cases in paperboard as compared to 175 cases in glass.

The weight analysis for delivering 1,000 gallons of milk in each system is presented in Table 86. The container weight per 1,000 gallons of milk varies from 2.6 percent of the total for the one gallon container to 4.0 percent for the half pint container. The total weight for the half pint delivery system is 1.6 percent higher than the weight of the one gallon system.

TABLE 85

SYSTEM TRANSPORTATION FOR MANUFACTURE OF 1,000 POUNDS PAPERBOARD CONTAINERS

Transportation component	Gallon	Half gallon	Half pint
Pulpwood harvesting	(2,360 lb)	(2,310 lb)	(2,420 lb)
Rail - ton-miles	100	98	103
Truck - ton-miles	41	40	42
Paperboard	(1,060 lb)	(1,040 lb)	(1,090 lb)
Rail - ton-miles	319	313	328
Truck - ton-miles	29	29	30
Carton blanks	(1,000 lb)	(1,000 lb)	(1,000 lb)
Truck - ton-miles	78	78	78
Delivery			
Store or institutional			
Gasoline - gal.	1.8	1.8	1.8
Diesel	1.8	1.8	1.8
Home delivery			
Gasoline - gal.	17	17	

Source: References 22, 24, 25.

TABLE 86

WEIGHT ANALYSIS FOR DELIVERING 1,000 GALLONS OF MILK IN THE NONREFILLABLE PAPERBOARD SYSTEMS

	One gallon		Half gallon		Half pint	
Component	lb	%	lb	%	lb	%
Container	253	2.6	273	2.8	406	4.0
Cases	1,000	10.1	1,000	10.1	1,000	10.0
Milk	8,600	87.3	8,600	87.1	8,600	86.0
Total	9,853	100.0	9,873	100.0	10,006	100.0

Source: Midwest Research Institute.

7. Postconsumer solid waste and recycling: The volume occupied by the paperboard container in final disposal is estimated to be 22 percent of the original volume. The total volume (at 91 percent being landfilled) would be the sum of the paperboard volume, plus 22 percent of the original volume (as void space). The density of the paperboard milk carton was estimated to be 42 pounds per cubic foot.

The nonrefillable nature of paperboard milk cartons dictates that after the milk is consumed, the carton is discarded into the postconsumer waste stream. At the present time, there is no favorable method for recovering this fiber in a "closed loop" recycling process by which the fiber could be used to manufacture new milk cartons; although some experimental programs are underway for recovery of half pint milk containers from schools and institutions. However, as the technology and implementation of resource recovery systems advance, this wood fiber may be recovered and burned for its energy value.

F. Nonrefillable Plastic Pouch

1. Raw materials extracting and processing: The discussions of the impacts for natural gas and crude oil extraction, natural gas processing, crude distillation/hydrotreat, and ethylene manufacture are presented in Section C-1.

Low density polyethylene (LDPE) resin manufacture: In the manufacture of LDPE, ethylene is mixed with catalysts and additives, and pressurized to approximately 40,000 psig. Polymerization is generally carried out in jacketed tubular reactors. The heat of polymerization is removed and used to generate process steam. After the reaction is complete, the pressure is reduced and molten polymer is separated in flash drums. The polymer is solidified and chopped into pellets.

Table 87 lists the raw impacts for producing 1,000 pounds of LDPE. Much of the information was obtained from manufacturers, and agrees very closely with published literature values. The waterborne wastes conform to the guidelines stated in Reference 47.

TABLE 87

DATA FOR MANUFACTURE OF 1,000 POUNDS OF LOW DENSITY POLYETHYLENE

Impact category	Value	Source
Raw materials		42,55
Ethylene	1,042 lb	
Other	20 lb	55
Energy		42,55
Electric	498 kw-hr	
Natural gas	3,240 cu ft	
Water (wastewater volume)	1,000 gal.	47
Solid wastes, process	9.0 cu ft	55
Atmospheric emissions, process		
Hydrocarbons	3.0 lb	55
Waterborne wastes		
BOD	0.20 lb	47
COD	2.0 lb	47
TSS	0.55 lb	47

2. Low density polyethylene film manufacture: There are two manufacturing methods used in producing polyethylene film--blown and chill cast techniques. The blown film method is most widely used. In the blown film process, polyethylene pellets are fed into an extruder where they are heated to a homogeneous melt, and then forced through a tubular die having an annular opening. The molten film is inflated with air to form a bubble with the desired diameter. The film is cooled by air blowing, and wound onto a spool.

A modern extruder operates nearly adiabatically. The thermal energy provided by barrel heaters is about equivalent to the heat lost by barrel cooling and other losses. Almost all of the applied horsepower to the extruder is used to heat the resin to the extrusion temperature generally around 400 F. The theoretical horsepower requirement for extrusion can be calculated from heat capacity data and the temperature profile of the resin. Industry sources report that approximately 286 Btu of energy is required to extrude 1 pound of polyethylene. After extrusion, additional energy (in the form of refrigeration) is required to cool the blown film.

In this report the following data were used for calculating the energy requirements for polyethylene film extrusion.

1. The power consumption for extrusion of polyethylene is 8 pounds per hour per horsepower, which converts to 125 horsepower required for each 1,000 pounds of plastic extruded. The actual drive horsepower is assumed to be 50 percent higher, or 187 horsepower for 1,000 pounds per hour of film.

2. The electrical barrel heaters were estimated to consume 10 percent of the extrusion horsepower, or 18.7 horsepower.

3. The specific heat of low density polyethylene is approximately 0.5 cal/g/°C.

4. The extrusion temperature is 400 F.

5. The heat content of the extruded plastic is 184 Btu per pound.

6. The energy required to cool 1,000 pounds of extruded polyethylene is 96 horsepower (75 percent efficiency).

7. The power required to run auxiliary equipment (winding machine, conveyors, grinders, etc.) is estimated to be 25 horsepower.

8. The total power requirement for manufacturing 1,000 pounds of polyethylene film is 327 horsepower or 245 kilowatt-hour.

The material loss in a modern plant is reported to be less than 0.5 percent.

The impact data for manufacturing 1,000 pounds of polyethylene film are shown in Table 88.

3. Nonrefillable plastic pouch form, fill, and seal manufacture: The plastic pouch is widely used for packaging milk in Canada. However, in the United States the pouch is just beginning to penetrate the dairy market.

In the profile diagram for the plastic pouch, LDPE resin is converted into a 3 milliliter sheet of film, and wound on a paper spool. The spool is wrapped with plastic and shipped to the dairy where it is filled with milk and sealed, thus forming the plastic pouch container.

The half gallon size uses 168.75 square inches of film per pouch. One pound of film will produce an average of 59.26 pouches. The filling and sealing machine has an output of 25 one-half gallon pouches per minute.

TABLE 88

DATA FOR MANUFACTURE OF 1,000 POUNDS OF LOW DENSITY POLYETHYLENE FILM

Impact category	Value	Source
Raw materials		37
LDPE resin	1,005 lb	
Energy		37
Electric	245 kw-hr	
Water	1,780 gal.	37
Solid waste	5 lb	37

The half pint size requires 44.9 square inches per pouch, resulting in 222.72 pouches from 1 pound of film.

A gallon package of milk in the pouch container generally consists of two one-half gallon containers packaged in a separate plastic bag which weighs 12 to 15 grams.

To use the plastic pouch (except the half pint size) it is first placed in a pitcher; then the corner of the pouch extending from the pitcher is cut off. After pouring the desired quantity of milk from the pouch, the end of the pouch is sealed by pulling into a slit in the pitcher.

The pitcher for the one half gallon size weighs 173 grams and is assumed to have a useful life of at least 2 years. Assuming 730 uses in 2 years, the pitcher would contribute 1.06 pounds of plastic for each 1,000 gallons of milk packaged in the half gallon pouch.

The weight of a one half gallon pouch is 7.65 grams or 0.01686 pound. The weight of 2,000 half gallon containers is 33.7 pounds. Therefore, the pitcher represents about 3 percent of the resin requirements for the plastic pouch. The impact profile for the pitcher was not researched. Its weight was accounted for by increasing the weight of the plastic film system by 1.06 pounds per 1,000 gallons of milk packaged.

The half pint pouch weighs 2.04 grams and requires a straw for drinking the milk. The straw weight is 0.3 gram, and contributes 10.58 pounds of resin to the 1,000 gallon half pint pouch system. The straw represents 12.8 percent by weight of the pouch/straw combination. The impacts for the straw manufacturing process were not researched. The impacts of the straw were accounted for by increasing the weight of the LDPE film system by 10.58 pounds per 1,000 gallons of milk packaged.

The LDPE film used in forming the plastic pouch is received as a 36- to 55-pound roll of plastic film wound on a paper spool. The spool is placed in the pouch forming and filling machine where the production rate is 25 half gallon containers and 40 half pint containers per minute. The loss from this operation is estimated to be 0.5 percent. Two of the half gallon size pouches are generally placed in a separate plastic bag and sold as 1 gallon of milk.

Table 89 presents the basic impact values for forming and filling 1,000 gallons of milk for each container size.

TABLE 89

DATA FOR FORMING AND FILLING 1,000 GALLONS
OF PLASTIC POUCH MILK CONTAINERS

Impact category	One Gallon	Half gallon	Half pint	Source
Energy				
Electric, kw-hr	1.09	1.09	8.67	76
Water volume, gal.	33.3	33.3	167.0	76
Solid waste, lb	0.57	0.57	0.76	37
Waterborne wastes, lb				15,37
BOD	0.16	0.16	0.16	
COD	0.24	0.24	0.24	

4. Secondary packaging: A 36-pound roll of LDPE film is wrapped on a paper spool weighing 447.3 grams. The spool is then placed in a plastic bag weighing 44 grams. The spools are generally shipped as a pallet containing 27 rolls of film. The packaging requirements reduce

to 27.4 pounds of paper and 2.7 pounds of LDPE bags for 1,000 pounds of film material.

The weight of plastic film wrapped on one roll may vary from 36 to 55 pounds. The packaging described above represents the actual weights of the paper spool and plastic bag used in two dairies operating on the west coast (Refs. 77 and 78).

5. Transportation profile: The ton-miles of transportation for 1,000 pounds of the low density polyethylene film system is summarized in Table 90. Resin transportation accounts for about 70 percent of each container system total ton-miles.

TABLE 90

TRANSPORTATION PROFILE FOR 1,000 POUNDS OF LOW DENSITY POLYETHYLENE FILM SYSTEM
(ton-miles)

Container size	Subsystem	Transportation mode Rail	Truck	Barge	Pipeline
One gallon	Ethylene system	5.0	1.0	1	8
	LDPE resin	21.0	4.0		
	LDPE film	3.0	3.0		
	Packaging	0.1	0.1		
	Total	29.1	8.1	1	8
Half gallon	Ethylene system	3.0	1.0	1	4
	LDPE resin	11.0	2.0		
	LDPE film	2.0	2.0		
	Packaging	0.1	0.1		
	Total	16.1	5.1	1	4
Half pint	Ethylene system	6.0	2.0	1	9
	LDPE resin	25.0	4.0		
	LDPE film	4.0	4.0		
	Packaging	0.2	0.1		
	Total	35.2	10.1	1	9

Source: Midwest Research Institute.

Table 91 presents the weight analysis for delivering 1,000 gallons of milk in the plastic pouch systems. For each pouch system, the weight contribution of the milk container is less than 1 percent of the total payload delivered by the truck.

TABLE 91

WEIGHT ANALYSIS FOR DELIVERING 1,000 GALLONS OF MILK IN THE NONREFILLABLE PLASTIC POUCH SYSTEMS

Component	One gallon		Half gallon		Half pint	
	lb	%	lb	%	lb	%
Containers	61.3	0.6	33.7	0.3	72.0	0.7
Cases	1,000.0	10.4	1,000.0	10.4	1,000.0	10.3
Milk	8,600.0	89.0	8,600.0	89.3	8,600.0	89.0
Total	9,661.3	100.0	9,633.7	100.0	9,672.0	100.0

Source: Midwest Research Institute.

The fuel requirements for delivering the plastic pouches are assumed to be the same as those required for the refillable plastic, nonrefillable plastic, and paperboard container system (Table I-67).

6. Postconsumer solid waste and recycling: The plastic pouch will compress to essentially a zero percent void space. Therefore, 1,000 pounds of the plastic will occupy 17.42 cubic feet or 15.85 cubic feet allowing for 9 percent to be incinerated.

Table 92 contains the summary of the postconsumer solid waste data for 1,000 gallons of each plastic pouch system. The volume of landfill occupied is very small when compared to the other milk container systems due to the small quantity of raw materials required and the absence of a void space in compacting.

The plastic material in the landfill represents a potential for energy recovery. The heat content of the plastic is about 20,000 Btu per pound. Therefore, 1,000 gallons of the one gallon pouch system would represent 1.2 million Btu of energy at 100 percent recovery. In this report, the energy credit has not been applied to the plastic pouch systems.

TABLE 92

POSTCONSUMER SOLID WASTE FOR 1,000 GALLONS OF THE NONREFILLABLE PLASTIC POUCH SYSTEMS

Container size	Weight of plastic, lb	Volume of[d] plastic, cu ft
One gallon	62.3[a]	1.0
Half gallon	34.7[b]	0.6
Half pint	82.5[c]	1.4

Source: Midwest Research Institute.

[a] Includes weights of the pouches, outer bags, and serving pitchers.

[b] Includes weights of the pouches and serving pitchers.

[c] Includes weights of the pouches and straws.

[d] Assuming 91 percent landfill and plastic density of 57.4 pounds per cubic foot.

G. Closure Systems

The weight of milk container closures vary from 0.65 gram to over 6 grams per closure. The materials of construction include aluminum, steel, paper/aluminum, paper, polyethylene, and polystyrene. In this report, only plastic and paper closures were used. This is not to imply that other closures are inferior. The scope of the study did not allow a thorough treatment of all closure systems.

The nonrefillable plastic gallon and half gallon containers were assigned a 2.3 gram plastic closure, while the one-way half pint container was assigned a 0.65 gram paper closure. The refillable plastic and glass gallon and half gallon containers were assumed to require a 2.3 gram paper closure, with the half pint sizes using the 0.65 gram closure.

Companies which manufacture closures were contacted to obtain the materials and energy balance for the closure manufacturing process. However, responses were too few in number to obtain an accurate representation of the energy requirements. Therefore, estimates of the energy requirements for manufacturing the closures were made.

Table 93 contains the summary of estimates used to represent the paper and plastic closure manufacture.

TABLE 93

DATA FOR MANUFACTURE OF 1,000 POUNDS OF CLOSURES

Category	Plastic	Paper
Energy		
Electric, kw-hr	1,054	1,657
Natural gas, cu ft		2,400
Solid waste, lb	20.0	37.0
Water volume, gal.	1,500	--

Source: Midwest Research Institute.

H. Secondary Packaging Manufacture

In this report the secondary packaging includes plastic film and corrugated containers. The plastic film is made from low density polyethylene resin, and the corrugated medium uses both unbleached kraft paper and NSSC paper. The tables in Section I contain the total resource and environmental profile data for 1,000 pounds of each material.

I. Computer Tables

This section of the Appendix contains the computer printouts showing the resource and environmental impacts associated with a stated quantity (usually 1,000 pounds) of the basic processes and systems used in this report.

Impact data are presented for the following processes and systems:

Table 94	Crude Oil Production
	Natural Gas Production
	Natural Gas Processing
	Crude Distillation Hydrotreat
	Ethylene Manufacture
	High Density Polyethylene Resin Manufacture
	Low Density Polyethylene Resin Manufacture

Table 95	HDPE Resin System
	LDPE Resin System
	LDPE Film Manufacturing
	Corrugated System
	Unbleached Kraft Pulp and Paper Manufacturing
	Corrugated Container Manufacturing
Table 96	Pulpwood Harvest
	Bleached Kraft Pulp and Paperboard Manufacture
	Converting Gallon Paperboard Container
	Converting Half Gallon Paperboard Container
	Converting Half Pint Paperboard Container
Table 97	1,000 Gallons of Each Gallon Container System
Table 98	1,000 Gallons of Each Half Gallon Container System
Table 99	1,000 Gallons of Each Half Pint Container System

TABLE 94

IMPACTS FOR BASIC SYSTEMS

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS

THOU LB EACH SYS

		CRUDE OIL PROD THOU LB	NATURAL GAS PROD THOU LB	NATURAL GAS PROC THOU LB	CRUDE DISTILL HYDROTRT	ETHYLENE MFG THOU LB	ETHYLENE SYS THOU LB	HDPE RESIN MFG THOU LB	LDPE RESIN MFG THOU LB
INPUTS TO SYSTEMS									
NAME	UNITS								
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	19.617	.033	.004	.022	.166	5.202	.961	1.301
ENERGY SOURCE NAT GAS	MILL BTU	.325	23.845	.821	.611	7.552	26.749	1.814	2.497
ENERGY SOURCE COAL	MILL BTU	.032	.032	.009	.052	.403	.456	2.333	3.158
ENERGY SOURCE MISC	MILL BTU	.007	.007	.002	.012	.091	.103	.527	.714
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	1.880	0.000	0.000	1.000	5.000	5.732	50.000	20.000
ENERGY PROCESS	MIL BTU	.437	.066	.835	.697	8.213	9.184	5.636	7.669
ENERGY TRANSPORT	MIL BTU	.020	.608	0.000	0.000	0.000	.472	0.000	0.000
ENERGY OF MATL RESOURCE	MIL BTU	19.525	23.244	0.000	0.000	0.000	22.854	0.000	0.000
WATER VOLUME	THOU GAL	.083	.041	.294	.211	.491	.819	.970	1.122
OUTPUTS FROM SYSTEMS									
NAME	UNITS								
SOLID WASTES PROCESS	POUND	.600	0.000	0.000	1.000	18.000	18.405	4.500	4.500
SOLID WASTES FUEL COMB	POUND	.207	.194	.050	.307	2.371	2.689	13.723	18.573
SOLID WASTES MINING	POUND	.517	.517	.137	.836	6.456	7.300	37.369	50.578
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	.051	.045	.013	.076	.655	.731	3.162	4.825
ATMOS NITROGEN OXIDES	POUND	1.952	3.527	4.805	.423	4.765	11.723	5.495	7.459
ATMOS HYDROCARBONS	POUND	9.201	26.903	11.381	1.032	7.993	39.910	7.765	8.781
ATMOS SULFUR OXIDES	POUND	.279	.218	2.676	.594	2.388	4.804	12.838	17.377
ATMOS CARBON MONOXIDE	POUND	.539	.966	1.285	.081	.961	2.836	.722	.982
ATMOS ALDEHYDES	POUND	.002	.001	.000	.001	.015	.017	.010	.014
ATMOS OTHER ORGANICS	POUND	.001	.001	.000	.003	.036	.038	.015	.021
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	.000	0.000	.001	0.000	.000	0.000	0.000
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	0.000	0.000	0.000	.000	0.000	0.000
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	6.146	2.116	.144	.109	1.340	4.671	.424	.581
WATERBORNE BOD	POUND	.000	.000	.000	.014	.058	.062	.181	.201
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.000	.000
WATERBORNE OIL	POUND	.110	.037	.000	.004	.000	.058	.000	.000
WATERBORNE COD	POUND	.000	.000	.000	.071	.000	.019	1.763	2.004
WATERBORNE SUSP SOLIDS	POUND	.000	.000	.000	.010	.088	.091	.482	.552
WATERBORNE ACID	POUND	.010	.010	.003	.016	.124	.140	.716	.969
WATERBORNE METAL ION	POUND	.002	.002	.001	.004	.031	.035	.179	.242
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	.000	0.000	.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS									
NAME	UNITS								
RAW MATERIALS	POUNDS	1.880	0.000	0.000	1.000	5.000	5.732	50.000	20.000
ENERGY	MIL BTU	19.982	23.918	.835	.697	8.213	32.510	5.636	7.669
WATER	THOU GAL	.083	.041	.294	.211	.491	.819	.970	1.122
INDUSTRIAL SOLID WASTES	CUBIC FT	.018	.010	.003	.029	.362	.383	.750	.994
ATM EMMISSIONS	POUNDS	12.026	31.662	20.161	2.212	16.814	60.059	30.007	39.459
WATERBORNE WASTES	POUNDS	6.270	2.166	.147	.229	1.641	5.075	3.745	4.551
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MIL BTU	19.617	.033	.004	.022	.166	5.202	.961	1.301
ENERGY SOURCE NAT GAS	MIL BTU	.325	23.845	.821	.611	7.552	26.749	1.814	2.497
ENERGY SOURCE COAL	MIL BTU	.032	.032	.009	.052	.403	.456	2.333	3.158
ENERGY SOURCE NUCL HYPWR	MIL BTU	.007	.007	.002	.012	.091	.103	.527	.714
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 95

IMPACTS FOR BASIC SYSTEMS

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS

THOU LB EACH PROC

		HDPE RESIN SYS THOU LB	LDPE RESIN SYS THOU LB	LDPE FILM MFG THOU LB	CORRUG SYS THOU LB	UNBLCH KRF PULP PAP MFG THOU LB	CORRUG CONT MFG THOU LB
INPUTS TO SYSTEMS							
NAME	UNITS						
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	697.000	689.000	697.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	6.423	6.763	.527	4.587	5.244	4.497
ENERGY SOURCE NAT GAS	MILL BTU	29.900	30.583	.532	2.900	3.629	2.900
ENERGY SOURCE COAL	MILL BTU	2.812	3.637	1.279	2.766	3.325	2.766
ENERGY SOURCE MISC	MILL BTU	.636	.822	.289	0.000	0.000	0.000
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	0.000	0.000	5.853	7.258	5.853
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	56.018	26.018	0.000	70.000	70.000	70.000
ENERGY PROCESS	MIL BTU	15.279	17.312	2.626	16.016	19.631	16.016
ENERGY TRANSPORT	MIL BTU	.496	.496	0.000	.090	0.000	0.000
ENERGY OF MATL RESOURCE	MIL BTU	23.996	23.996	0.000	0.000	0.000	0.000
WATER VOLUME	THOU GAL	1.830	1.982	1.822	.317	.368	.312
OUTPUTS FROM SYSTEMS							
NAME	UNITS						
SOLID WASTES PROCESS	POUND	23.826	23.826	5.000	67.000	67.000	67.000
SOLID WASTES FUEL COMB	POUND	16.546	21.397	7.522	45.355	57.335	45.332
SOLID WASTES MINING	POUND	45.035	58.243	20.482	39.520	47.500	39.520
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	3.930	5.593	1.592	39.038	43.806	38.931
ATMOS NITROGEN OXIDES	POUND	17.804	19.768	2.769	16.226	18.704	16.130
ATMOS HYDROCARBONS	POUND	49.670	50.687	1.078	9.749	11.653	9.652
ATMOS SULFUR OXIDES	POUND	17.882	22.421	7.031	55.481	40.460	55.458
ATMOS CARBON MONOXIDE	POUND	3.700	3.960	.343	5.618	5.634	4.972
ATMOS ALDEHYDES	POUND	.028	.032	.005	.084	.089	.076
ATMOS OTHER ORGANICS	POUND	.055	.060	.006	8.089	10.638	8.062
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	.000	0.000	.012	.013	.011
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	0.000	.002	.000	.000
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	5.329	5.486	.152	5.483	6.406	5.435
WATERBORNE BOD	POUND	.246	.266	.000	20.506	20.507	20.506
WATERBORNE PHENOL	POUND	.000	.000	.000	.002	.002	.002
WATERBORNE SULFIDES	POUND	.000	.001	.000	.003	.003	.003
WATERBORNE OIL	POUND	.061	.061	.000	.003	.003	.003
WATERBORNE COD	POUND	1.782	2.023	.002	.023	.026	.023
WATERBORNE SUSP SOLIDS	POUND	.577	.648	.001	9.514	15.016	9.514
WATERBORNE ACID	POUND	.863	1.116	.392	.420	.505	.420
WATERBORNE METAL ION	POUND	.216	.279	.098	.105	.126	.105
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	.760	.880	.760
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	.000	.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS							
NAME	UNITS						
RAW MATERIALS	POUNDS	56.018	26.018	0.000	767.000	759.000	767.000
ENERGY	MIL BTU	39.771	41.805	2.626	16.106	19.631	16.016
WATER	THOU GAL	1.830	1.982	1.822	.317	.368	.312
INDUSTRIAL SOLID WASTES	CUBIC FT	1.153	1.397	.446	2.050	2.320	2.050
ATM EMMISSIONS	POUNDS	93.069	102.521	12.824	134.300	130.999	133.292
WATERBORNE WASTES	POUNDS	9.074	9.879	.645	36.819	43.475	36.770
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MIL BTU	6.423	6.763	.527	4.587	5.244	4.497
ENERGY SOURCE NAT GAS	MIL BTU	29.900	30.583	.532	2.900	3.629	2.900
ENERGY SOURCE COAL	MIL BTU	2.812	3.637	1.279	2.766	3.325	2.766
ENERGY SOURCE NUCL HYPWR	MIL BTU	.636	.822	.289	0.000	0.000	0.000
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	0.000	0.000	5.853	7.258	5.853

TABLE 96

IMPACTS FOR BASIC SYSTEMS

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS

PAPERBOARD PROCESSES

		PULPWOOD HARVEST THOU LB	BL KRAFT PAPERBRD MFG THOU LB	CONVERT GAL PBD THOU LB	CONVERT HGAL PBD THOU LB	CONVERT HPT PBD THOU LB
INPUTS TO SYSTEMS						
NAME	UNITS					
MATERIAL WOOD FIBER	POUNDS	0.000	530.000	0.000	0.000	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	.129	6.239	.032	.032	.032
ENERGY SOURCE NAT GAS	MILL BTU	0.000	3.384	.149	.149	.149
ENERGY SOURCE COAL	MILL BTU	0.000	4.351	.072	.072	.072
ENERGY SOURCE MISC	MILL BTU	0.000	.247	.016	.016	.016
ENERGY SOURCE WOOD FIBER	MILL BTU	0.000	9.530	0.000	0.000	0.000
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	76.000	42.000	27.000	54.000
ENERGY PROCESS	MIL BTU	0.000	23.750	.267	.267	.267
ENERGY TRANSPORT	MIL BTU	.129	0.000	.002	.002	.002
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000
WATER VOLUME	THOU GAL	.008	10.736	.004	.004	.004
OUTPUTS FROM SYSTEMS						
NAME	UNITS					
SOLID WASTES PROCESS	POUND	0.000	119.000	1.000	1.000	1.000
SOLID WASTES FUEL COMB	POUND	.032	54.216	.424	.424	.424
SOLID WASTES MINING	POUND	0.000	17.472	1.154	1.154	1.154
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	.154	6.718	.092	.092	.092
ATMOS NITROGEN OXIDES	POUND	.138	9.422	.221	.221	.221
ATMOS HYDROCARBONS	POUND	.140	5.650	.176	.176	.176
ATMOS SULFUR OXIDES	POUND	.034	16.638	.398	.398	.398
ATMOS CARBON MONOXIDE	POUND	.927	1.563	.049	.049	.049
ATMOS ALDEHYDES	POUND	.011	.004	.001	.001	.001
ATMOS OTHER ORGANICS	POUND	.040	.005	.002	.002	.002
ATMOS ODOROUS SULFUR	POUND	0.000	.400	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	0.000	.000	.000	.000
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.003	0.000	.000	.000	.000
ATMOS MERCURY	POUND	0.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.069	3.789	.030	.030	.030
WATERBORNE BOD	POUND	.000	4.400	.000	.000	.000
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000
WATERBORNE OIL	POUND	.000	.000	.000	.000	.000
WATERBORNE COD	POUND	.001	.001	.000	.000	.000
WATERBORNE SUSP SOLIDS	POUND	.000	7.801	.000	.000	.000
WATERBORNE ACID	POUND	.000	.835	.022	.022	.022
WATERBORNE METAL ION	POUND	.000	.204	.006	.006	.006
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS						
NAME	UNITS					
RAW MATERIALS	POUNDS	0.000	606.000	42.000	27.000	54.000
ENERGY	MIL BTU	.129	23.750	.269	.269	.269
WATER	THOU GAL	.008	10.736	.004	.004	.004
INDUSTRIAL SOLID WASTES	CUBIC FT	.000	2.574	.035	.035	.035
ATM EMMISSIONS	POUNDS	1.445	40.400	.937	.937	.937
WATERBORNE WASTES	POUNDS	.071	17.031	.058	.058	.058
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MIL BTU	.129	6.239	.032	.032	.032
ENERGY SOURCE NAT GAS	MIL BTU	0.000	3.384	.149	.149	.149
ENERGY SOURCE COAL	MIL BTU	0.000	4.351	.072	.072	.072
ENERGY SOURCE NUCL HYPWR	MIL BTU	0.000	.247	.016	.016	.016
ENERGY SOURCE WOOD WASTE	MIL BTU	0.000	9.530	0.000	0.000	0.000

TABLE 97

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS ONE THOUSAND GALLONS OF EACH ONE GALLON CONTAINER SYSTEM

NAME	UNITS	PAPERBRD GAL SYS THOU GAL	GLASS GAL SYS 5 TRIP THOU GAL	GLASS GAL SYS 10 TRIP THOU GAL	GLASS GAL SYS 20 TRIP THOU GAL	OW-PLS GAL SYS THOU GAL	RET-PLS GAL SYS 5 TRIP THOU GAL	RET-PLS GAL SYS 10 TRIP THOU GAL	RET-PLS GAL SYS 20 TRIP THOU GAL	RET-PLS GAL SYS 50 TRIP THOU GAL	PS POUCH GAL SYS THOU GAL
INPUTS TO SYSTEMS											
MATERIAL WOOD FIBER	POUNDS	137.894	32.128	17.408	10.047	7.679	12.435	7.542	5.095	3.628	.648
MATERIAL LIMESTONE	POUND	39.840	288.171	144.491	72.651	0.000	.800	.800	.800	.800	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	29.755	1.976	1.976	1.976	0.000	1.647	1.779	1.844	1.884	0.000
MATERIAL GLASS SAND	POUND	0.000	426.240	213.120	106.560	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	138.240	69.120	34.560	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	48.000	24.000	12.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	2.942	1.955	1.484	1.250	2.432	1.567	1.191	1.004	.889	1.248
ENERGY SOURCE NAT GAS	MILL BTU	1.708	4.345	2.286	1.256	5.226	2.584	1.385	.785	.425	1.950
ENERGY SOURCE COAL	MILL BTU	1.413	.713	.401	.246	.869	.578	.345	.228	.158	.314
ENERGY SOURCE MISC	MILL BTU	.128	.117	.067	.042	.190	.118	.070	.046	.031	.070
ENERGY SOURCE WOOD FIBER	MILL BTU	2.423	.296	.172	.119	.064	.130	.089	.068	.056	.005
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	31.385	19.395	9.917	5.178	10.018	6.996	4.713	3.571	2.886	1.687
ENERGY PROCESS	MIL BTU	6.968	6.118	3.279	1.859	3.498	2.341	1.387	.910	.624	1.268
ENERGY TRANSPORT	MIL BTU	1.126	1.307	1.131	1.043	1.251	.926	.837	.793	.764	.826
ENERGY OF MATL RESOURCE	MIL BTU	.531	.000	.000	.000	4.032	1.710	.855	.428	.171	1.496
WATER VOLUME	THOU GAL	2.872	1.292	.857	.639	.657	.693	.551	.479	.436	.317
OUTPUTS FROM SYSTEMS											
SOLID WASTES PROCESS	POUND	36.732	21.048	12.765	8.623	8.355	6.819	5.640	5.050	4.697	2.425
SOLID WASTES FUEL COMB	POUND	15.916	5.700	3.302	2.103	5.713	4.165	2.570	1.773	1.294	2.063
SOLID WASTES MINING	POUND	10.011	130.300	65.753	33.479	13.869	8.956	5.250	3.397	2.285	5.020
SOLID WASTE POST-CONSUM	CUBIC FT	30.386	19.920	10.020	5.020	75.430	16.243	8.455	5.055	2.003	1.052
ATMOS PARTICULATES	POUND	2.972	5.959	3.096	1.665	1.677	1.368	.802	.519	.350	.576
ATMOS NITROGEN OXIDES	POUND	5.278	6.336	4.069	2.936	5.876	3.840	2.667	2.081	1.727	2.742
ATMOS HYDROCARBONS	POUND	3.874	5.882	3.502	2.313	9.854	5.025	2.965	1.937	1.317	3.962
ATMOS SULFUR OXIDES	POUND	6.840	6.773	3.760	2.253	5.990	4.160	2.480	1.640	1.136	2.157
ATMOS CARBON MONOXIDE	POUND	6.411	6.986	5.994	5.503	6.983	5.006	4.468	4.212	4.032	4.336
ATMOS ALDEHYDES	POUND	.072	.092	.076	.069	.081	.059	.054	.051	.049	.051
ATMOS OTHER ORGANICS	POUND	.367	.605	.402	.301	.386	.318	.238	.198	.173	.188
ATMOS ODOROUS SULFUR	POUND	.100	.002	.002	.002	0.000	.002	.002	.002	.002	0.000
ATMOS AMMONIA	POUND	.003	.004	.004	.003	.003	.003	.002	.002	.002	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.014	.015	.014	.014	.015	.011	.011	.010	.010	.010
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	.148	.014	.014	.014	0.000	.011	.012	.013	.013	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	2.028	1.801	1.189	.883	1.597	1.033	.747	.605	.518	.764
WATERBORNE BOD	POUND	1.439	1.121	.687	.470	.429	.565	.399	.326	.282	.197
WATERBORNE PHENOL	POUND	.001	.001	.001	.001	.001	.000	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.001	.001	.001	.001	.001	.001	.001	.001	.000	.001
WATERBORNE OIL	POUND	.002	.001	.001	.001	.011	.005	.003	.002	.001	.004
WATERBORNE COD	POUND	.051	.010	.007	.006	.308	.132	.068	.036	.017	.130
WATERBORNE SUSP SOLIDS	POUND	2.286	1.055	.724	.558	.446	.541	.464	.425	.402	.292
WATERBORNE ACID	POUND	.355	.191	.109	.068	.263	.171	.102	.068	.047	.097
WATERBORNE METAL ION	POUND	.075	.047	.027	.017	.066	.042	.025	.017	.011	.024
WATERBORNE CHEMICALS	POUND	.006	.032	.016	.008	.008	.011	.005	.003	.001	.001
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	2.000	2.000	2.000	0.000	1.600	1.800	1.900	1.960	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	0.000	0.000	.000	.000	.000	.000	.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	.000	.000	.000	.000	0.000	.000	.000	.000	.000	0.000
WATERBORNE LEAD	POUND	.000	.000	.000	.000	0.000	.000	.000	.000	.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS											
RAW MATERIALS	POUNDS	238.875	954.151	480.032	242.972	17.697	21.878	14.834	11.311	9.198	2.335
ENERGY	MIL BTU	8.624	7.425	4.410	2.903	8.781	4.978	3.079	2.131	1.559	3.588
WATER	THOU GAL	2.872	1.292	.857	.639	.657	.693	.551	.479	.436	.317
INDUSTRIAL SOLID WASTES	CUBIC FT	.846	2.120	1.105	.597	.377	.269	.182	.138	.112	.128
ATM EMMISSIONS	POUNDS	26.078	32.668	20.933	15.073	30.865	19.803	13.701	10.666	8.809	14.026
WATERBORNE WASTES	POUNDS	6.243	6.259	4.761	4.013	3.130	4.081	3.614	3.381	3.240	1.510
POST-CONSUMER SOL WASTE	CUBIC FT	30.386	19.920	10.020	5.020	75.430	16.243	8.455	5.055	2.003	1.052
ENERGY SOURCE PETROLEUM	MIL BTU	2.942	1.955	1.484	1.250	2.432	1.567	1.191	1.004	.889	1.248
ENERGY SOURCE NAT GAS	MIL BTU	1.708	4.345	2.286	1.256	5.226	2.584	1.385	.785	.425	1.950
ENERGY SOURCE COAL	MIL BTU	1.413	.713	.401	.246	.869	.578	.345	.228	.158	.314
ENERGY SOURCE NUCL HYPWR	MIL BTU	.128	.117	.067	.042	.190	.118	.070	.046	.031	.070
ENERGY SOURCE WOOD WASTE	MIL BTU	2.423	.296	.172	.110	.064	.130	.089	.068	.056	.005

TABLE 98

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS ONE THOUSAND GALLONS OF EACH HALF GALLON CONTAINER SYSTEM

		PAPERBRD H GAL SY THOU GAL	GLASS H GAL SY 5 TRIP THOU GAL	GLASS H GAL SY 10 TRIP THOU GAL	GLASS H GAL SY 20 TRIP THOU GAL	DW-PLS H GAL SY THOU GAL	RET-PLS H GAL SY 5 TRIP THOU GAL	RET-PLS H GAL SY 10 TRIP THOU GAL	RET-PLS H GAL SY 20 TRIP THOU GAL	RET-PLS H GAL SY 50 TRIP THOU GAL	PS POUCH H GAL SY THOU GAL
INPUTS TO SYSTEMS											
NAME	UNITS										
MATERIAL WOOD FIBER	POUNDS	145.274	42.707	24.030	14.691	8.754	20.711	13.360	9.153	6.842	.065
MATERIAL LIMESTONE	POUND	42.720	366.204	183.910	92.763	0.000	1.600	1.600	1.600	1.600	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	31.906	2.577	2.577	2.577	0.000	2.245	2.376	2.442	2.481	0.000
MATERIAL GLASS SAND	POUND	0.000	540.792	270.396	135.198	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	175.392	87.696	43.848	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	60.900	30.450	15.225	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	3.061	2.349	1.760	1.464	2.690	2.070	1.481	1.181	1.003	1.079
ENERGY SOURCE NAT GAS	MILL BTU	1.756	5.519	2.906	1.599	6.116	4.225	2.297	1.330	.751	1.118
ENERGY SOURCE COAL	MILL BTU	1.497	.988	.593	.395	1.028	1.023	.616	.411	.289	.181
ENERGY SOURCE MISC	MILL BTU	.136	.164	.101	.069	.225	.210	.125	.082	.056	.041
ENERGY SOURCE WOOD FIBER	MILL BTU	2.576	.410	.253	.175	.074	.225	.163	.128	.108	.001
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	29.214	24.884	12.858	6.846	11.698	10.249	6.571	4.679	3.564	.937
ENERGY PROCESS	MIL BTU	7.384	7.953	4.352	2.551	4.111	4.054	2.454	1.641	1.158	.724
ENERGY TRANSPORT	MIL BTU	1.145	1.477	1.260	1.152	1.305	1.006	.881	.817	.780	.787
ENERGY OF MATL RESOURCE	MIL BTU	.507	.000	.000	.000	4.716	2.694	1.347	.674	.270	.858
WATER VOLUME	THOU GAL	3.070	1.589	1.037	.761	.724	1.259	1.014	.891	.817	.214
OUTPUTS FROM SYSTEMS											
NAME	UNITS										
SOLID WASTES PROCESS	POUND	39.046	26.393	15.883	10.629	9.713	9.427	7.422	6.368	5.756	1.604
SOLID WASTES FUEL COMB	POUND	16.837	7.784	4.743	3.222	6.701	7.171	4.452	3.057	2.234	1.252
SOLID WASTES MINING	POUND	10.461	166.466	84.571	43.623	16.407	15.788	9.332	6.073	4.129	2.896
SOLID WASTE POST-CONSUM	CUBIC FT	30.984	21.040	10.640	5.440	75.799	17.352	9.682	5.000	2.647	.583
ATMOS PARTICULATES	POUND	3.023	7.655	4.024	2.208	1.947	2.254	1.335	.845	.563	.349
ATMOS NITROGEN OXIDES	POUND	5.462	7.918	5.050	3.615	6.662	5.637	3.720	2.747	2.169	2.068
ATMOS HYDROCARBONS	POUND	3.945	7.341	4.330	2.824	11.381	7.698	4.419	2.770	1.784	2.555
ATMOS SULFUR OXIDES	POUND	7.060	8.974	5.152	3.242	7.011	7.022	4.190	2.730	1.872	1.319
ATMOS CARBON MONOXIDE	POUND	6.509	7.920	6.715	6.107	7.270	5.543	4.795	4.392	4.165	4.120
ATMOS ALDEHYDES	POUND	.073	.105	.086	.076	.083	.065	.057	.053	.050	.049
ATMOS OTHER ORGANICS	POUND	.347	.730	.474	.346	.411	.408	.290	.222	.185	.169
ATMOS ODOROUS SULFUR	POUND	.107	.004	.004	.004	0.000	.004	.004	.004	.004	0.000
ATMOS AMMONIA	POUND	.003	.005	.004	.003	.003	.003	.002	.002	.002	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.014	.017	.016	.015	.016	.012	.011	.011	.010	.010
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	.159	.017	.017	.017	0.000	.014	.015	.015	.016	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	2.111	2.207	1.434	1.047	1.785	1.427	.978	.748	.612	.599
WATERBORNE BOD	POUND	1.454	1.376	.826	.551	.468	.742	.519	.392	.322	.172
WATERBORNE PHENOL	POUND	.001	.001	.001	.001	.001	.001	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.001	.001	.001	.001	.001	.001	.001	.001	.001	.000
WATERBORNE OIL	POUND	.002	.001	.001	.001	.013	.008	.004	.002	.001	.003
WATERBORNE COD	POUND	.049	.011	.009	.007	.359	.206	.105	.055	.024	.077
WATERBORNE SUSP SOLIDS	POUND	2.396	1.272	.852	.643	.478	.681	.558	.490	.451	.267
WATERBORNE ACID	POUND	.377	.266	.162	.110	.311	.302	.182	.122	.085	.056
WATERBORNE METAL ION	POUND	.079	.066	.040	.027	.078	.075	.045	.030	.021	.014
WATERBORNE CHEMICALS	POUND	.004	.041	.020	.010	.010	.017	.009	.004	.002	.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	2.000	2.000	2.000	0.000	1.600	1.800	1.900	1.960	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	0.000	0.000	.000	.000	.000	.000	.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	.000	.000	.000	.000	0.000	.000	.000	.000	.000	0.000
WATERBORNE LEAD	POUND	.000	.000	.000	.000	0.000	.000	.000	.000	.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS											
NAME	UNITS										
RAW MATERIALS	POUNDS	249.114	1213.456	611.917	311.148	20.452	34.805	23.907	17.874	14.487	1.007
ENERGY	MIL BTU	9.036	9.430	5.612	3.703	10.132	7.753	4.682	3.132	2.208	2.370
WATER	THOU GAL	3.070	1.589	1.037	.761	.724	1.259	1.014	.891	.817	.214
INDUSTRIAL SOLID WASTES	CUBIC FT	.896	2.709	1.420	.776	.443	.437	.286	.209	.164	.078
ATM EMMISSIONS	POUNDS	26.702	40.686	25.872	18.458	34.785	28.660	18.838	13.791	10.821	10.441
WATERBORNE WASTES	POUNDS	6.475	7.243	5.346	4.397	3.503	5.060	4.201	3.743	3.480	1.188
POST-CONSUMER SOL WASTE	CUBIC FT	30.984	21.040	10.640	5.440	75.799	17.352	9.682	5.000	2.647	.583
ENERGY SOURCE PETROLEUM	MIL BTU	3.061	2.349	1.760	1.464	2.690	2.070	1.481	1.181	1.003	1.079
ENERGY SOURCE NAT GAS	MIL BTU	1.756	5.519	2.906	1.599	6.116	4.225	2.297	1.330	.751	1.118
ENERGY SOURCE COAL	MIL BTU	1.497	.988	.593	.395	1.028	1.023	.616	.411	.289	.181
ENERGY SOURCE NUCL HYPWR	MIL BTU	.136	.164	.101	.069	.225	.210	.125	.082	.056	.041
ENERGY SOURCE WOOD WASTE	MIL BTU	2.576	.410	.253	.175	.074	.225	.163	.128	.108	.001

TABLE 99

RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS ONE THOUSAND GALLONS OF EACH HALF PINT CONTAINER SYSTEM

NAME	UNITS	PAPERBRD H PT SYS THOU GAL	GLASS H PT SYS 5 TRIP THOU GAL	GLASS H PT SYS 10 TRIP THOU GAL	GLASS H PT SYS 20 TRIP THOU GAL	OW-PLS H PT SYS THOU GAL	RET-PLS H PT SYS 5 TRIP THOU GAL	RET-PLS H PT SYS 10 TRIP THOU GAL	RET-PLS H PT SYS 20 TRIP THOU GAL	RET-PLS H PT SYS 50 TRIP THOU GAL	PS POUCH H PT SYS THOU GAL
INPUTS TO SYSTEMS											
MATERIAL WOOD FIBER	POUNDS	219.706	116.586	79.785	61.384	33.095	45.422	28.788	20.471	15.480	1.379
MATERIAL LIMESTONE	POUND	62.560	731.376	372.176	192.576	3.669	3.669	3.669	3.669	3.669	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	46.724	11.062	11.062	11.062	2.740	3.790	3.921	3.987	4.026	0.000
MATERIAL GLASS SAND	POUND	0.000	1065.600	532.800	266.400	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	345.600	172.800	86.400	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	120.000	60.000	30.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY SOURCE PETROLEUM	MILL BTU	4.145	4.175	3.048	2.477	5.005	3.325	2.115	1.514	1.148	1.249
ENERGY SOURCE NAT GAS	MILL BTU	3.215	11.138	5.988	3.414	14.056	9.450	5.380	3.347	2.126	2.659
ENERGY SOURCE COAL	MILL BTU	2.392	2.700	1.921	1.532	2.650	2.065	1.302	.921	.692	.464
ENERGY SOURCE MISC	MILL BTU	.238	.448	.323	.260	.563	.420	.262	.184	.136	.104
ENERGY SOURCE WOOD FIBER	MILL BTU	3.831	1.391	1.082	.927	.394	.498	.358	.288	.246	.012
ENERGY SOURCE HYDROPOWER	MILL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	55.280	53.789	30.093	18.245	28.437	20.341	12.086	7.962	5.486	2.336
ENERGY PROCESS	MIL BTU	11.453	17.976	10.880	7.331	10.336	8.865	5.682	4.091	3.137	1.805
ENERGY TRANSPORT	MIL BTU	1.123	1.875	1.482	1.279	1.626	1.079	.831	.710	.632	.655
ENERGY OF MATL RESOURCE	MIL BTU	1.261	.003	.003	.003	10.706	5.815	2.907	1.454	.582	2.027
WATER VOLUME	THOU GAL	4.508	3.462	2.378	1.835	2.115	3.475	3.098	2.911	2.798	.524
OUTPUTS FROM SYSTEMS											
SOLID WASTES PROCESS	POUND	58.171	59.386	38.678	28.324	25.731	17.183	12.411	10.027	8.596	3.320
SOLID WASTES FUEL COMB	POUND	25.984	21.255	15.272	12.279	17.437	14.408	9.187	6.578	5.012	2.932
SOLID WASTES MINING	POUND	18.477	336.963	175.594	94.909	41.131	31.700	19.604	13.558	9.930	7.422
SOLID WASTE POST-CONSUM	CUBIC FT	35.529	26.140	13.340	6.940	79.564	19.866	10.796	6.261	3.540	1.369
ATMOS PARTICULATES	POUND	4.994	16.096	8.945	5.368	4.797	4.582	2.704	1.766	1.202	.805
ATMOS NITROGEN OXIDES	POUND	8.036	15.826	10.211	7.396	13.992	10.499	6.644	4.728	3.562	3.208
ATMOS HYDROCARBONS	POUND	6.395	14.037	8.141	5.185	24.855	15.819	8.894	5.438	3.358	4.938
ATMOS SULFUR OXIDES	POUND	11.740	21.123	13.603	9.841	17.179	14.053	8.531	5.773	4.115	3.038
ATMOS CARBON MONOXIDE	POUND	6.086	9.220	7.089	5.972	8.604	5.674	4.218	3.496	3.053	2.964
ATMOS ALDEHYDES	POUND	.065	.129	.095	.077	.094	.065	.049	.042	.037	.034
ATMOS OTHER ORGANICS	POUND	.446	1.164	.672	.423	.622	.625	.366	.236	.158	.138
ATMOS ODOROUS SULFUR	POUND	.156	.032	.032	.032	.009	.009	.009	.009	.009	0.000
ATMOS AMMONIA	POUND	.003	.007	.005	.004	.004	.003	.002	.002	.002	.002
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.010	.015	.013	.012	.014	.008	.007	.006	.006	.006
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUND	.233	.059	.059	.059	.014	.022	.023	.023	.023	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	2.962	4.124	2.619	1.863	3.501	2.553	1.608	1.137	.852	.801
WATERBORNE BOD	POUND	2.265	2.756	1.673	1.131	1.032	1.357	.844	.588	.434	.224
WATERBORNE PHENOL	POUND	.001	.002	.001	.001	.001	.001	.001	.000	.000	.000
WATERBORNE SULFIDES	POUND	.001	.002	.001	.001	.001	.001	.001	.001	.000	.000
WATERBORNE OIL	POUND	.004	.002	.001	.001	.028	.016	.008	.004	.002	.006
WATERBORNE COD	POUND	.112	.017	.012	.009	.808	.439	.221	.113	.047	.174
WATERBORNE SUSP SOLIDS	POUND	3.505	2.643	1.815	1.402	1.033	1.101	.814	.670	.584	.316
WATERBORNE ACID	POUND	.608	.736	.531	.429	.794	.607	.383	.271	.204	.142
WATERBORNE METAL ION	POUND	.130	.179	.128	.103	.197	.150	.094	.067	.050	.036
WATERBORNE CHEMICALS	POUND	.014	.080	.040	.020	.023	.036	.018	.009	.004	.002
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	2.000	2.000	2.000	0.000	1.600	1.800	1.900	1.960	0.000
WATERBORNE CHROMIUM	POUND	.000	0.000	0.000	0.000	.000	.000	.000	.000	.000	.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.000
WATERBORNE LEAD	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.000
WATERBORNE PHOSPHATES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ZINC	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE AMMONIA	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUMMARY OF ENVIRONMENTAL IMPACTS											
RAW MATERIALS	POUNDS	384.270	2444.013	1258.715	666.067	67.941	73.222	48.464	36.088	28.661	3.71[illegible]
ENERGY	MIL BTU	13.837	19.854	12.365	8.613	22.668	15.759	9.419	6.256	4.351	4.4[illegible]7
WATER	THOU GAL	4.508	3.462	2.378	1.835	2.115	3.475	3.098	2.911	2.798	.524
INDUSTRIAL SOLID WASTES	CUBIC FT	1.386	5.638	3.099	1.829	1.138	.854	.556	.407	.318	.145
ATM EMMISSIONS	POUNDS	38.165	77.710	48.865	34.369	70.185	51.360	31.448	21.519	15.526	15.133
WATERBORNE WASTES	POUNDS	9.603	12.542	8.823	6.960	7.419	7.861	5.792	4.760	4.138	1.701
POST-CONSUMER SOL WASTE	CUBIC FT	35.529	26.140	13.340	6.940	79.564	19.866	10.796	6.261	3.540	1.369
ENERGY SOURCE PETROLEUM	MIL BTU	4.145	4.175	3.048	2.477	5.005	3.325	2.115	1.514	1.148	1.249
ENERGY SOURCE NAT GAS	MIL BTU	3.215	11.138	5.988	3.414	14.056	9.450	5.380	3.347	2.126	2.659
ENERGY SOURCE COAL	MIL BTU	2.392	2.700	1.921	1.532	2.650	2.065	1.302	.921	.692	.464
ENERGY SOURCE NUCL HYPWR	MIL BTU	.238	.448	.323	.260	.563	.420	.262	.184	.136	.104
ENERGY SOURCE WOOD WASTE	MIL BTU	3.831	1.391	1.082	.927	.394	.498	.358	.288	.246	.012

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22. The data on harvesting were derived by the American Paper Institute from a study by the American Pulpwood Association (which is now published). These data were applied as closely as possible to specific mill sites representing 83.2 percent of the paperboard manufactured for use in milk cartons.

23. Data were derived by the American Paper Institute (API) specifically for this study. The technique used was to survey that sector of the paper industry which manufacture milk carton paperboard utilizing data from API's annual Capacity Survey and its most recent complete Energy Survey. These two surveys contain detailed production and energy statistics for the eleven mill properties which manufacture 100 percent of the milk carton board in the U.S. The base year for these surveys was 1973. The information contained in the surveys were combined into a milk carton paperboard industry composite and these composite data were used as the basis for the mill energy figures. Specific data relating to harvesting and converting were not available in these surveys, and the API conducted additional surveys with a number of their member companies in order to derive data in these areas for this study. It was not feasible to survey 100 percent of the industry for these additional aspects of this study in the time available; but an in-depth analysis was made of the companies which produce 91 percent

of the milk carton paperboard. Based on the available information at these companies, additional data composites were constructed, and below are listed the percentages which represent the portion of the paperboard industry (based on production of milk carton paperboard) which had information available for the various parts of the study.

Energy Consumption for Harvesting	69.2%
Energy Consumption for Mill Operations	100.0%
Energy Consumption for Converting Operations	87.8%
Mill Material Balance	80.3%
Converting Material Balance	87.7%
Environmental Impact: Woodlands Water Effluents	N/A
Environmental Impact: Mill Water Effluents	90.6%
Environmental Impact: Converting Water Effluents	87.8%
Environmental Impact: Woodlands Air Emissions	83.2%
Environmental Impact: Mill Air Emissions	90.6%
Environmental Impact: Converting Air Emissions	90.6%
Environmental Impact: Woodlands Solid Waste	90.6%
Environmental Impact: Converting Solid Waste	90.6%
Transportation: Mill to Converter	87.7%
Transportation: Converter to Dairy	61.7%

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